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(54) **CONTROL-OPERATION ASSISTING DEVICE AND CONTROL-OPERATION ASSISTING METHOD**

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Description

[0001] The present invention relates to a control-operation assisting device in particular according to the preamble of independent claim 1 that assists a control operation of an operator for an controlled object and a control-operation assisting method. A control-operation assisting device according to the preamble of independent claim 1 can be taken from the prior art document DE 10 2006 033 458 A1.

[0002] Prior art document EP 1 889 775 A2 discloses a method for correcting the steering angle in an assisted power steering for a motor vehicle. Said method involves determining corrective moment, which is superimposed to an auxiliary moment and induced into a steering system for influencing a wheel guidance angle. The determination of the corrective moment depends on a corrective steering angle. The corrective steering angle is determined depending on an actual-driving mode and a preset target-driving mode. The presetting of the target-driving mode takes place by a vehicle model which sustains a preset desired steering angle as input parameter.

[0003] Prior art document JP 2007-305079 A provide an assistance controller which appropriately perform assistance control performed in accordance with an object position, in accordance with the error accuracy of location positioning. Said document discloses an accuracy error in positioning the location of one's own vehicle is calculated on the basis of information on execution history of map matching and information on update history of a map database, and an accuracy error level in performing positioning is specified among a plurality of gradual levels on the basis of the calculated accuracy error with reference to a prescribed map. Then, a control level of assistance control to be performed in accordance with the position of the one's own vehicle is changed in accordance with the specified accuracy error level.

[0004] Prior art document JP 2007-182198 A provide a driving support device for a vehicle, for correctly and appropriately supporting driving at an appropriate timing according to a travelling state. Said driving support device for the vehicle includes: a vehicle position measuring means for measuring a vehicle position; a driving support means for supporting the driving of the vehicle according to the measured vehicle position; a high-precision vehicle position measuring means for measuring the vehicle position with higher precision compared with the vehicle position measuring means; a measurement precision determining means for determining measurement precision, from the measurement states of the vehicle position measuring means and the high-precision vehicle position measuring means; and a driving support level control means for controlling a support level by the driving support means, from the measurement precision determined by the measurement precision determining means.

[0005] Conventionally, as disclosed in Japanese Patent Application Laid-open No. H9-156528, there has been known a vehicle-operation assisting device that detects an advancing-direction azimuth angle of a vehicle and a tangential-direction azimuth angle of a road on which the vehicle travels and generates a steering torque in an orientation toward which a deviation between the detected advancing-direction azimuth angle and tangential-direction azimuth angle is decreased, thereby generating a steering force in a direction in which the vehicle is not departed from the road.

[0006] The conventional vehicle-operation assisting device is configured to output steering control based only on a deviation between the advancing-direction azimuth angle and the tangential-direction azimuth angle at a control point, without regard to a state of the vehicle operation of a driver and an environment on a periphery of the vehicle. Thus, according to the conventional vehicle-operation assisting device, steering control not suitable for the state of the vehicle operation of a driver (driving intension) and the environment on a periphery of the vehicle is outputted. This sometimes makes a driver feel a sense of discomfort or inconvenience for the steering control.

[0007] It is the object of the present invention to provide a control-operation assisting device and method that assists a control operation of an operator for a controlled object and a control-operation assisting method that improves driving comfort and steering control.

[0008] According to the present invention said object is solved by a control-operation assisting device having the features of independent claim 1. Preferred embodiments are laid down in the dependent claims. Moreover, said object is solved by a control-operation assisting method having the features of independent claim 21.

[0009] According to the first aspect, a system provided with an assistance-controller for assisting an operator of the system, comprises: a system-state detecting unit that detects information about an operational state of the system; an ideal-state generating unit that generates an ideal state of the system depending on at least the system-state detected by the system-state detecting unit; an ideal-input calculating unit that calculates an ideal input for the system so as to operate along the ideal state generated by the ideal-state generating unit; a system-input interface for converting an operator-control action into a control signal for the system; a difference calculating unit that calculates a difference between the ideal input calculated by the ideal-input calculating unit and the actual control-signal that the system-input interface provides to the system; wherein the system-input interface comprises the assistance-controller, and the assistance-controller determines at least one conversion-parameter pertaining to the conversion of the operator control-action into the control signal for the system depending on the difference calculated by the difference calculating unit so as to assist the operator in the operation of the system.

[0010] According to the second aspect, a control-operation assisting device that assists control operation of an operator on the manipulator for control of a controlled object, comprises: a controlled-object-state detection

unit that detects information about the state of the controlled object; a manipulator-state detection unit that detects information about the state of manipulator; an environment-state detection unit that detects information about the state of control operation environment on the periphery of the controlled object; an ideal-interaction generating unit that generates the ideal interaction dynamics between the controlled object and the environment from the information about the state of the controlled object detected by the controlled-object-state detection unit and the environmental state detected by the environment-state detection unit; an ideal-manipulator-impedance generation unit that generates an ideal impedance for the manipulator from the ideal interaction dynamics between controlled object and the environment generated by the ideal-interaction generating unit; a manipulator-impedance-controller assistance system that controls the impedance of the manipulator based on the ideal manipulator impedance generated by the ideal-manipulator-impedance generating unit to produce the desired interaction dynamics between the controlled object and the environment; an ideal-manipulator-control-signal generating unit that generates an ideal manipulator control signal from the ideal interaction dynamics between controlled object and the environment generated by the ideal-interaction generating unit; a manipulator-control-signal-ditrerence calculating unit that calculates the difference between the ideal manipulator control signal generated by the ideal-manipulator-control-signal generating unit and the state of the manipulator detected by the manipulator-state detection unit; an operation-precision estimation unit that estimates the precision required for the control operation of the controlled object from the ideal interaction dynamics between the controlled object and the environment generated by the ideal-interaction generating unit; a control-difference-impedance generating unit that generates a control difference impedance from the required precision estimated by the operation-precision estimation unit; an actuator-torque-controller-assistance system that controls the additional torque produced by the actuator based on the magnitude of the difference calculated by the manipulator-control-signal-difference calculating unit and the difference impedance calculated by the control-difference-impedance generating unit to assist the control-operation of the operator on the manipulator to achieve the required operation precision.

[0011] According to the third aspect, from information about a vehicle operation state and information about a vehicle operation environment, an ideal control path of an operation target object is generated; a control history of an operation system for the operation target object to operate along the generated ideal control path is calculated as an ideal control signal; a difference between the calculated ideal control signal and the information about the vehicle operation state is calculated; the operation system is controlled based on a magnitude of the calculated difference to assist the operation of the operator for the operation system; from the information about the vehicle operation state and/or the information about the vehicle operation environment, an accuracy required for the vehicle operation of the operation target object is estimated; and a control level of the operation system is increased as the estimated accuracy is higher.

[0012] A system-state detecting unit of the first aspect corresponds to a controlled-object-state detection unit, a manipulator-state detection unit, and environment-state detection unit of the second aspect, and a vehicle-operation-state detecting unit and an environment-state detecting unit of the third aspect.

[0013] An ideal-state generating unit of the first aspect corresponds to an ideal-interaction generating unit of the second aspect, and an ideal-control-path generating unit of the third aspect.

[0014] A assistance controller of the first aspect corresponds to an actuator-torque-controller-assistance system of the second aspect, and an operation-system assistance controller of the third aspect.

[0015] An ideal-input calculating unit of the first aspect corresponds to an ideal-manipulator-impedance generation unit of the second aspect, and an ideal-control-signal calculating unit of the third aspect.

[0016] A system-input interface unit of the first aspect corresponds to a manipulator-impedance-controller assistance system and ideal-manipulator-control-signal generating unit of the second aspect, and an ideal-control-signal calculating unit of the third aspect.

[0017] A difference calculating unit of the first aspect corresponds to a manipulator-control-signal-difference calculating unit of the second aspect of the present invention, and a difference calculating unit of the third aspect.

[0018] A operation-precision estimation unit of the second aspect corresponds to an operation-system assistance controller of the third aspect.

[0019] A control-difference-impedance generating unit of the second aspect corresponds to an operation-precision estimating unit of the third aspect.

Brief Description of the Drawings

[0020]

Fig. 1 is a block diagram showing a configuration of a control-operation assisting device according to the present invention.

Fig. 2 is a block diagram showing a configuration of a vehicle-operation assisting device according to a first embodiment of the present invention.

Fig. 3 is a functional block diagram showing the configuration of the vehicle-operation assisting device according to the present invention.

Fig. 4 is a flowchart showing a flow of a vehicle-operation assistance control process according to the first embodiment of the present invention.

Fig. 5 is an explanatory diagram of a process for

detecting a vehicle position and orientation in the environment at step S1 shown in Fig. 4.

Fig. 6 is an explanatory diagram of a generation process of a target travel location when the vehicle travels on a straight route at step S2 shown in Fig. 4.

Fig. 7 is an explanatory diagram of a generation process of a target travel location when the vehicle travels on a curved route at step S2 shown in Fig. 4.

Fig. 8 is a graph showing one example of a relation between the road-width of the road on which the vehicle travels and the accuracy required for the steering operation.

Fig. 9 is a graph showing one example of a torque output rule used for the process at step S8 shown in Fig. 4.

Fig. 10 is a block diagram showing the configuration of a vehicle-operation assisting device according to the second embodiment of the present invention.

Fig. 11 is a flowchart showing the flow of the vehicle-operation assistance control process according to the second embodiment of the present invention.

Fig. 12 is an explanatory diagram of a generation process of the target travel path of the vehicle at step S 15 shown in Fig. 11.

Fig. 13 is a graph showing one example of a relation between a driving load of a driver and an accuracy required for a steering operation.

Fig. 14 is an explanatory diagram of a modification of the generation process of the target travel path of the vehicle at step S15 shown in Fig. 11.

Fig. 15 is a block diagram showing a configuration of a vehicle-operation assisting device according to a third embodiment of the present invention.

Fig. 16 is a flowchart showing a flow of a vehicle-operation assistance control process according to the third embodiment of the present invention.

Figs. 17(a), 17 (b), and 17 (c) are graphs showing one example of relations between: the accuracy required for the steering operation; and an illumination on a periphery of the vehicle, weather, and a travel time zone of the vehicle, respectively.

Fig. 18 is a graph showing one example of a relation between the accuracy required for the steering operation and the number of target travel locations set when the target travel path is generated.

Fig. 19 is a block diagram showing a configuration of a vehicle-operation assisting device according to a fourth embodiment of the present invention.

Fig. 20 is a flowchart showing the flow of the vehicle-operation assistance control process according to the fourth embodiment of the present invention.

Fig. 21 is an explanatory diagram of generation and correction processes of the target travel location at step S44 shown in Fig. 20.

Fig. 22 is a graph showing one example of the torque output rule used for the process at step S50 shown in Fig. 20.

Fig. 23 is a graph showing one example of a relation between a driving technique of the driver and a distance L_0 shown in Fig. 21.

Fig. 24 is the block diagram showing a configuration of the vehicle-operation assisting device according to the fifth embodiment of the present invention.

Fig. 25 is a flowchart showing the flow of the vehicle-operation assistance control process according to the fifth embodiment of the present invention.

Fig. 26 is a graph showing one example of the torque output rule used for the process at step S71 shown in Fig. 25.

[0021] A control-operation assisting device system according to the present invention assists the control operation of an operator for the control of a controlled object. As shown in Fig. 1 a control-operation assisting device according to the present invention, comprises: an environment state detection unit 101, a controlled object state detection unit 102, an ideal interaction generating unit 103, an ideal manipulator control signal generating unit 104, an operation precision estimation unit 105, an ideal manipulator impedance generating unit 106, a manipulator control signal difference calculating unit 107, a control difference impedance generating unit 108, an actuator torque controller assistance system 109, manipulator impedance controller assistance system 110, an actuator 111, a manipulator 112, and a manipulator state detection unit 113.

[0022] The environment state detection unit 101 detects information about the state of control operation environment on the periphery of the controlled object 114. the controlled object state detection unit 102 detects information about the state of the controlled object 114. The ideal interaction generating unit 103 generates the ideal interaction dynamics between the controlled object 114 and the environment from the information about the state of the controlled object 114 detected by the controlled object state detection unit 102 and the environmental state detected by the environment state detection unit 101.

[0023] The ideal manipulator control signal generating unit 104 generates an ideal manipulator control signal from the ideal interaction dynamics between controlled object 114 and the environment generated by the ideal-interaction generating unit 103. The operation precision estimation unit 105 estimates the precision required for the control operation of the controlled object 114 from the ideal interaction dynamics between the controlled object 114 and the environment generated by the ideal-interaction generating unit 103.

[0024] The ideal manipulator impedance generating unit 106 generates an ideal impedance for the manipulator 112 from the ideal interaction dynamics between controlled object 114 and the environment generated by the ideal-interaction generating unit 103. The manipulator control signal difference calculating unit 107 calculates the difference between the ideal manipulator control signal generated by the ideal-manipulator-control-signal

generating unit and the state of the manipulator 112 detected by the manipulator-state detection unit 113.

[0025] The control difference impedance generating unit 108 generates a control difference impedance from the required precision estimated by the operation precision estimation unit 105. The actuator torque controller assistance system 109 controls the additional torque produced by the actuator 111 based on the magnitude of the difference calculated by the manipulator control signal difference calculating unit 107 and the difference impedance calculated by the control difference impedance generating unit 108 to assist the control operation of the operator on the manipulator 112 to achieve the required operation precision.

[0026] The manipulator impedance controller assistance system 110 controls the impedance of the manipulator 112 based on the ideal manipulator impedance generated by the ideal manipulator impedance generating unit 106 to produce the desired interaction dynamics between the controlled object 114 and the environment

[0027] Configurations of a vehicle-operation assisting device according to first to fifth embodiments of the present invention will be explained below with reference to the drawings. In the following embodiments, for a control object operated by an operator, a vehicle is assumed. However, the present invention is not limited to the embodiments, and can be applied to operation control objects, as a whole, in which a human is involved in control, such as an unmanned vehicle control over a large distance (UAVs in air or space), a tele-operated surgery (over distance or in size), an aviation and flight simulation, a factory worker/dancer/sportsman, an (micro)-assembly(over distance or in size).

[0028] When the present invention is applied to the unmanned vehicle control, operator assisting device, operator, controlled object, control input signal, control input profile, Ideal interaction between control object and environment, manipulator actuator, environment, and constraints of interaction between controlled object and environment of the present invention corresponds to tele-operation assisting device, tele-operator, remotely controlled vehicle, manipulator output signal, control input profile, ideal 3D trajectory of remotely controlled vehicle, stick actuator, road conditions (weather conditions, location of static and dynamic objects), and TTC to static or dynamic objects (restricted areas, communication time delays), respectively.

[0029] When the present invention is applied to the tele-operated surgery, operator assisting device, operator, controlled object, control input signal, control input profile, Ideal interaction between control object and environment, manipulator actuator, environment, and constraints of interaction between controlled object and environment of the present invention corresponds to surgery assisting device, surgeon, robotic surgical device, manipulator output signal, manipulator output profile, ideal placement and exerted forces of remotely controlled surgical device, haptic glove actuators, location of damageable tissues (properties of fluids in which the gripper moves, location of tissue that needs to be operated on), and TTC to static or dynamic objects (restricted areas, communication time delays), respectively.

[0030] When the present invention is applied to the aviation and flight simulation, operator assisting device, operator, controlled object, control input signal, control input profile, Ideal interaction between control object and environment, manipulator actuator, environment, and constraints of interaction between controlled object and environment of the present invention corresponds to aircraft flying assisting device, pilot, aircraft / helicopter, stick signal, stick output profile, ideal 3D trajectory of aircraft, stick actuator, distance to ground and no-go areas (location and orientation of landing zone, distance to other planes), and TTC to static or dynamic objects (restricted areas), respectively.

[0031] When the present invention is applied to the a factory worker/dancer/sportsman, operator assisting device, operator, controlled object, control input signal, control input profile, Ideal interaction between control object and environment, manipulator actuator, environment, and constraints of interaction between controlled object and environment of the present invention corresponds to body movement assisting device (haptic suit), factory worker/dancer /sportsman, human body, body movement control signals (pressures on body, limb torques, and position control signals), body movement profile, ideal exerted forces by limbs or ideal limb movement path (each rigid body separately but constraint), haptic suit or body movement support suit (pressure and actuators), location of objects (properties of such objects, muscle activity profiles necessary to perform limb movements well, contact forces with objects that need to be manipulated), and TTC to static or dynamic objects (restricted areas, communication time delays), respectively.

[0032] When the present invention is applied to the (micro)-assembly, operator assisting device, operator, controlled object, control input signal, control input profile, Ideal interaction between control object and environment, manipulator actuator, environment, and constraints of interaction between controlled object and environment of the present invention corresponds to assembly assisting device, assembler, remotely controlled gripper, manipulator output signal, manipulator output profile, ideal placement and exerted forces of the remotely controlled gripper, haptic glove actuators (haptic master), location of objects (properties of such objects, contact forces with objects that need to be manipulated), and TTC to static or dynamic objects (restricted areas, communication time delays), respectively.

First Embodiment

[0033] First, with reference to Fig. 2 to Fig. 9, the configuration of a vehicle-operation assisting device according to the first embodiment of the present invention is explained.

Configuration of vehicle-operation assisting device

[0034] A vehicle-operation assisting device 1 according to the first embodiment of the present invention is mounted on a vehicle as the control-object, and includes a vehicle-operation-state detecting device 2, an environment-state detecting device 3, a target-travel-point generating circuit 4, and an ideal-sbeering-signal calculating circuit 5, a difference calculating circuit 6, an operation-precision estimating circuit 7, and a steering system assistance control device 8, as main parts, as shown in Fig. 2.

[0035] The vehicle-operation-state detecting device 2 corresponds to a vehicle-operation-state detecting means 11 according to the present invention shown in Fig. 3. The vehicle-operation-state detecting device 2 includes various sensors such as a GPS (Global Positioning System), a speed sensor, an earth-magnetism sensor, an acceleration sensor, and a steering-angle sensor, and detects a position of the vehicle, a speed thereof, an advancing direction angle thereof, an acceleration thereof, and a steering angle thereof.

[0036] The environment-state detecting device 3 corresponds to an environment-state detecting means 12 according to the present invention shown in Fig. 3. The environment-state detecting device 3 includes an imaging device, a laser radar, an ultrasonic sensor, a navigation device, a roughness sensor, etc., arranged at a front and sides of the vehicle, and detects obstacles present in a periphery of the vehicle; the curvature profile, the lane width, and the roughness of the road on which the vehicle travels; and moving objects adjacent to the vehicle.

[0037] The target-travel-point generating circuit 4, the ideal-steering-signal calculating circuit 5, the difference calculating circuit 6, and the operation-precision estimating circuit 7 correspond to an ideal-control-path generating means 13, an ideal-conrol-signal calculating means 14, a difference calculating means 15, and an operation-precision estimating means 16 according to the present invention shown in Fig. 3, respectively. Functions (operations) of these circuits are realized by a microcomputer mounted on the vehicle executing a control program. The functions of the respective circuits are described later.

[0038] The steering-system assistance control device 8 corresponds to an operation-system assistance control unit 17 according to the present invention shown in Fig. 3. The steering-system assistance control device 8 is configured by a known electric power steering mechanism or power-assist mechanism arranged on a steering of the vehicle, and executes control for assisting the steering operation of the driver, which is described in detail later.

[0039] The vehicle-operation assisting device 1 having such a configuration executes the vehicle-operation-assistance control process shown below to output vehicle-operation assistance control suitable for the state of vehicle operation by the driver or the environment on the periphery of the vehicle. With reference to the flowchart shown in Fig. 4, the operation of the vehicle-operation assisting device 1 when executing the vehicle-operation assistance control process is explained below.

Vehicle-operation assistance control process

[0040] The flowchart shown in Fig. 4 is started when the ignition switch of the vehicle is switched from an off state to an on state, and the vehicle-operation assistance control process proceeds to the process at step S1. The vehicle-operation assistance control process is executed repeatedly for each predetermined control cycle.

[0041] In the process at step S1, the environment-state detecting device 3 detects a position of the vehicle within a traffic lane on which the vehicle is traveling. More specifically, the environment-state detecting device 3 extracts an edge image from a video in vehicle lateral directions photographed by the imaging device arranged on lateral sides of the vehicle to extract left and right lane markers L_L and L_R (see Fig. 5) of the traffic lane of the vehicle. The environment-state detecting device 3 calculates a center line Lc (see Fig. 5) of the traffic lane from the extracted left and right lane markers L_L and L_R to calculate a horizontal direction distance In (see Fig. 5) between the calculated center line Lc and a traveling position P_0 of a vehicle A. Thereby, the process at step S1 is completed, and the vehicle-operation assistance control process proceeds to a process at step S2.

[0042] In the process at step S2, the target-travel-point generating circuit 4 calculates from a current vehicle position a target travel location at which the vehicle should pass through in the future. More specifically, the target-travel-point generating circuit 4 obtains a video in a vehicle front direction via the environment-state detecting device 3, and extracts the edge image from the obtained video to detect a linear shape (curvature R) of the center line Lc of the traffic lane. The target-travel-point generating circuit 4 then sets the target travel location based on information about the detected linear shape. In the present embodiment, the target travel-point generating circuit 4 changes a setting method of the target travel location between when the vehicle travels on a straight route and when the vehicle travels on a curved route.

[0043] That is, when the vehicle travels on the straight route, the target-travel-point generating circuit 4 sets a position H[m] ahead of the current position P_b of the vehicle A to a target travel location P, as shown in Fig. 6. On the other hand, when the vehicle travels on the curved route, as shown in Fig. 7, the target-travel-point generating circuit 4 calculates a tangential line L_P for a lane borderline such as a lane marker on an inner side of the curved route passing at the current position P_0 of the vehicle A (in an example shown in Fig. 7, the right lane marker L_R), etc., and sets to the target travel location P, a point at which the calculated tangential line L_P crosses the center line L_c of the traffic lane. Thereby, the process at step S2 is completed, and the vehicle-operation as-

sistance control process proceeds to a process at step S3.

[0044] In the process at step S3, the ideal-steering-signal calculating circuit 5 calculates an ideal steering angle S to reach the target travel location P calculated by the process at step S2. More specifically, the ideal-steering-signal calculating circuit 5 inputs the information detected by the vehicle-operation-state detecting device 2 and the environment-state detecting device 3, into a driver model in which a value of the ideal steering angle S is 2-G-u-(v/L) (v denotes a vehicle speed, and G denotes a steering gain of the vehicle), where u denotes an angle formed by a vector connecting the current vehicle position P_0 and the target travel location P, and the vehicle advancing direction thereby to calculate the ideal steering angle S to reach the target travel location P calculated by the process at step S2. Thereby, the process at step S3 is completed, and the vehicle-operation assistance control process proceeds to a process at step S4.

[0045] In the process at step S4, the vehicle-operation-state detecting device 2 detects a current vehicle steering angle S. Thereby, the process at step S4 is completed, and the vehicle-operation assistance control process proceeds to a process at step S5.

[0046] In the process at step S5, the difference calculating circuit 6 calculates a difference δ (=S-S) between the ideal steering angle S calculated by the process at step S3 and the current vehicle steering angle S detected by the process at step S4. Thereby, the process at step S5 is completed, and the vehicle-operation assistance control process proceeds to a process at step S6.

[0047] In the process at step S6, the operation-precision estimating circuit 7 estimates an accuracy "a" of the steering operation required in a state of the driving environment on a periphery of the vehicle, detected by the environment-state detecting device 3. Generally, in traveling scenes such as when a road width of a traffic route is narrow, when the traffic route is crowded, when the vehicle enters a curved route, and when the surface roughness of the traffic route is low, the accuracy is required for the steering operation. On the other hand, in traveling scenes, such as when the vehicle is traveling on a long straight route or on an express way, the accuracy required for the steering operation is low. According, in the present embodiment, the operation-precision estimating circuit 7 previously holds a map showing a corresponding relationship between the traveling scene and the steering accuracy and references the map to estimate the required accuracy of the steering operation. More specifically, the operation-precision estimating circuit 7 previously holds a map, shown in Fig. 8, showing a corresponding relationship between a road width of the road on which the vehicle travels and the required accuracy of the steering operation, and reads from the map the accuracy of the steering operation corresponding to the road width of the traffic route detected by the environment-state detecting device 3 to estimate the required accuracy of the steering operation. Thereby, the process at step S6 is completed, and the vehicle-operation assistance control process proceeds to a process at step S7.

[0048] In the process at step S7, the steering-system assistance control device 8 changes a torque output rule used for a process at step S8 described later, based on: the horizontal direction distance In between the center line Lc of the traffic lane of the vehicle and the traveling position of the vehicle A, detected by the process at step S1; the difference δ between the ideal steering angle S calculated by the process at step S5 and the current vehicle steering angle S; and the steering accuracy "a" estimated by the process at step S6. In the present embodiment, the torque output rule is that in a power-assist mechanism for generating a torque of which the magnitude is proportional to that of the difference 8 between the ideal steering angle S and the current vehicle steering angle S, as indicated by a solid line L_1 in Fig, 9, and a torque T can be expressed by $T=K\times\delta$ where K denotes a constant of proportion.

[0049] The constant of proportion K is a function between the horizontal direction distance l_n and the steering operation accuracy "a", and is represented by an equation of: $K=F(l_n, a)= |l_n] \times a\times K_0$, for example. That is, the generated torque is changed according to a magnitude of the horizontal direction distance l_n and the steering accuracy "a". More specifically, the proportional constant K increases as the horizontal direction distance l_n and the steering accuracy "a" increase, and the torque output rule is changed as shown by a dotted line L2 in Fig. 9. On the other hand, the constant of proportion K decreases as the horizontal direction distance l_n and the steering operation accuracy "a" decrease, and the torque output rule is changed as indicated by a dotted line L3 in Fig. 9. Thereby, the process at step S7 is completed, and the vehicle-operation assistance control process proceeds to a process at step S8.

[0050] In the process at step S8, the steering-system assistance control device 8 implements control for generating the steering torque to a steering wheel. In the first embodiment, the steering-system assistance control device 8 has an electric motor as a mechanism for generating a steering force, and implements motor control according to the torque output rule set in the process at step S7. As a result, the driver feels the steering torque superposed on the steering wheel via the steering wheel. In the present embodiment, a repulsive force for the steering operation by the driver, written as the torque output rule, is controlled. In contrary, an induction force for a non-operation by the driver can be controlled. Thereby, the process at step S8 is completed, and a series of vehicle-operation assistance control processes are ended.

[0051] As is obvious from the explanations, according to the vehicle-operation assisting device 1 of the first embodiment of the present invention, the target-travel-point generating circuit 4 calculates the target travel location

at which the vehicle should pass in the future from the current vehicle position, the ideal-steering-signal calculating circuit 5 calculates the ideal steering angle S to reach the target travel location P, and the difference calculating circuit 6 calculates the difference δ between the ideal steering angle S and the current vehicle steering angle S. The steering-system assistance control device 8 controls a steering system based on the magnitude of the calculated difference δ to assist the vehicle operation of the driver. According to such a configuration, it is possible to provide the driver with steering operation assistance according to the magnitude of the difference δ from an ideal driving state, and thus, the vehicle-operation assistance control suitable for the state of the vehicle operation of the vehicle by the driver and the environment on a periphery of the vehicle can be outputted.

[0052] In the conventional vehicle-operation assisting device, an assistance control amount is amplified to recover a delay in time from the vehicle operation assistance is provided to the driver until the driver takes a control action, and as a result, a divergent system is sometimes generated. However, according to the driving assisting device 1 of the first embodiment of the present invention, as described above, the steering-system assistance control device 8 controls the steering system based on the magnitude of the difference δ between the ideal steering angle S and the current vehicle steering angle S, and thus, unlike in the conventional vehicle-operation assisting device, the present invention can inhibit the generation of the divergent system.

[0053] According to the vehicle-operation assisting device 1 of the first embodiment of the present invention, the operation-precision estimating circuit 7 estimates the steering operation accuracy "a", required in a state of the driving environment on a periphery of the vehicle, detected by the environment-state detecting device 3, the steering-system assistance control device 8 increases a control level of the steering system when the estimated steering operation accuracy "a" is higher. Thus, the vehicle operation assistance that matches the required steering operation precision in the current driving environment can be provided to the driver.

[0054] According to the vehicle-operation assisting device 1 of the first embodiment of the present invention, the ideal-steering-signal calculating circuit 5 inputs the information detected by the vehicle-operation-state detecting device 2 and the environment-state detecting device 3, into a driver model in which a value of the ideal steering angle S is 2 -G-u-(v/L) (v denotes a vehicle speed, and G denotes a steering gain of the vehicle), where u denotes an angle formed by: a vector connecting the current vehicle position P0 and the target travel location P; and the advancing direction of the vehicle thereby to calculate the ideal steering angle S. Thus, by the control path obtained by taking into consideration a steering characteristic of the driver, the steering operation of the driver can be assisted.

[0055] According to the vehicle-operation assisting device 1 of the first embodiment of the present invention, the steering-system assistance control device 8 controls a level of the repulsive force against the steering operation of the driver, written as the torque output rule, to control the control level of the steering system, and thus, it is possible to provide to the driver steering operation assistance by a torque change recognizes by the driver via the steering system.

Second Embodiment

[0056] With reference to Fig. 10 to Fig. 14, a configuration of the vehicle-operation assisting device according to the second embodiment of the present invention is explained next.

Configuration of vehicle-operation assisting device

[0057] As shown in Fig. 10, a vehicle-operation assisting device 20 according to the second embodiment of the present invention includes a travelable-region calculating circuit 21, an approximate-travel-region generating circuit 22, a target-travel-path generating circuit 23, an operation-signal prediction circuit 24, and a vehicle-operation-load estimating device 25, in addition to the vehicle-operation-state detecting device 2, the environment-state detecting device 3, the difference calculating circuit 6, and the steering-system assistance control device 8 in the vehicle-operation assisting device 10 according to the first embodiment,

[0058] The travelable-region calculating circuit 21, the approximate-travel-region generating circuit 22, the target-travel-path generating circuit 23, the operation-signal prediction circuit 24, and the vehicle-operation-load estimating device 25 correspond to a movable-region calculating means, an approximate-control-region calculating means, an ideal-control-path generating means, an operation-signal prediction means, and a vehicle-operation-load estimating means according to the present invention, respectively. These functions are realized by a microcomputer mounted on the vehicle executing a control program. The functions of the respective components are described later.

[0059] The vehicle-operation assisting device 20 having such a configuration executes a vehicle-operation-assistance control process shown below to output vehicle-operation assistance control suitable for a state of the vehicle operation of the vehicle by the driver or an environment on a periphery of the vehicle. With reference to a flowchart shown in Fig. 11, an operation of the vehicle-operation assisting device 20 when the vehicle-operation assistance control process is executed is explained below.

Vehicle-operation assistance control process

[0060] The flowchart shown in Fig. 11 is started at a timing at which an ignition switch of the vehicle is

switched from an off state to an on state, and the vehicle-operation assistance control process proceeds to a process at step S11. The vehicle-operation assistance control process is executed repeatedly for each predetermined control cycle.

[0061] In the process at step S11, the environment state detecting device 3 calculates the horizontal direction distance I_n between the center line Lc of the traffic lane and the current position P0 of the vehicle A (see Fig. 5) and a road width wr of the traffic lane (see Fig. 11). Thereby, the process at step S11 is completed, and the vehicle-operation assistance control process proceeds to a process at step S12.

[0062] In the process at step S12, the environment-state detecting device 3 determines whether there is an obstacle on the traffic lane on which the vehicle travels. When there is the obstacle, the environment-state detecting device 3 detects a distance ξ from the current position P0 of the vehicle A to an obstacle O and a width wo of the obstacle, as shown in Fig. 12. Thereby, the process at step S12 is completed, and the vehicle-operation assistance control process proceeds to a process at step S13.

[0063] In the process at step S13, the travelable-region calculating circuit 21 calculates a region over which the vehicle can travel within a traffc-lane region. More specifically, the travelable-region calculating circuit 21 calculates a travelable region R_1 from the width wr of the traffic lane of the vehicle A, the distance ξ to the obstacle O, and the obstacle wo, detected in the processes at steps S11 and S12, as shown in Fig. 12. Thereby, the process at step S13 is completed, and the vehicle-operation assistance control process proceeds to a process at step S14.

[0064] In the process at step S14, the approximate-travel-region generating circuit 22 approximately generates a travel region, which corresponds to the traffic lane, within the travelable region R_1 calculated by the process at step S13. More specifically, the approximate-travel-region generating circuit 22 previously holds templates of a curved route and a straight route, each having a predetermined road width, and determines, as an approximate travel region, a combination of a curved-route template and a straight-route template (in an example shown in Fig. 12, a combination of curved-route templates RR1, RR2, RR3, and RR4 and a straight-route template Rsi) that provides a largest area when the combination of the curved-route template and the straight-route template is applied within the travelable region R_1, as shown in Fig. 12. Thereby, the process at step S14 is completed, and the vehicle-operation assistance control process proceeds to a process at step S15.

[0065] In the process at step S15, the target-travel-path generating circuit 23 calculates, as a target travel path, a route of the vehicle that travels in the approximate travel region generated by the process at step S14. More specifically, as shown in Fig. 11, the target-travel-path generating circuit 23 calculates, as the target travel path, a route traveled by an ideal steering angle S' evaluated from an equation $S'=G\times H\times \nu$, where T denotes a central point of the approximate travel region H meters ahead of the current position P0 of the vehicle A and u denotes an angle formed by: a vector connecting the current position P0 of the vehicle A and the central point T; and the advancing direction of its own vehicle. In the second embodiment, a value of H is 15[m] and a value of G is 0.15. However, the value of G is desirably changed according to a type of vehicle, a driver, and a state of an environment Thereby, the process at step S15 is completed, and the vehicle-operation assistance control process proceeds to a process at step S16.

[0066] In the process at step S16, the operation-signal prediction circuit 24 utilizes the information detected by the vehicle-operation-state detecting device 2 to calculate a left-and-right direction position and an advancing direction angle of the vehicle within the route after an elapse of 1 second. In the second embodiment, for the left-and-right direction position, a left-and-right position in the approximate travel region calculated by the process at step S14, more specifically, a position at which the vehicle reaches when the ideal steering angle S' for realizing the target travel path calculated by the process at step S15 is maintained for 1 second, is adopted. The advancing direction angle is a advancing direction angle of the vehicle on the target travel path calculated by the process at step S 15, more specifically, an angle by which the vehicle rotates when the ideal steering angle S' for realizing the target travel path calculated by the process at step S15 is maintained for 1 second. Thereby, the process at step S16 is completed, and the vehicle-operation assistance control process proceeds to a process at step S17.

[0067] In the process at step S 17, the difference calculating circuit 6 calculates a difference between the left-and-right direction position and the advancing direction angle calculated by the process at step S16 for the target travel path calculated by the process at step S15. More specifically, the difference calculating circuit 6 calculates a relative distance between the vehicle position and the target travel path of the vehicle after an elapse of 1 second to calculate a positional difference d, and calculates a relative angle between the advancing direction angle and the target travel path of the vehicle after an elapse of 1 second to calculate a difference ϕ of the advancing direction angle. Thereby, the process at step S 17 is completed, and the vehicle-operation assistance control process proceeds to a process at step S18.

[0068] In the process at step S18, the vehicle-operation-load estimating device 25 estimates a vehicle-operation load WL of the driver. In the second embodiment, the vehicle-operation-load estimating device 25 uses a steering entropy method known by the time of the application of the invention of the subject application to estimate the vehicle-operation load WL of the driver. However, a physiological barometer, etc., such as a cardiac rate, of the driver can be used to estimate the same. The

vehicle-operation load WL of the driver becomes larger as the required steering operation accuracy "a" becomes larger, as shown in Fig. 12, and has a correlation with the steering operation accuracy "a". Thereby, the process at step S18 is completed, and the vehicle-operation assistance control process proceeds to a process at step S19.

[0069] In the process at step S19, the steering-system assistance control device 8 changes the torque output rule based on the positional difference d and the difference ϕ of the advancing direction angle calculated by the process at step S17 and the vehicle-operation load WL of the driver estimated by the process at step S18. In the second embodiment, the torque output rule is expressed as in an equation of: $T=K1\times(K2\times d+K3\times\phi)$. A constant of proportion K1 in the equation is a function, written as $K1=F(WL)=b\times WL$, for example, of the vehicle-operation load WL of the driver. That is, in the second embodiment, the generated torque T is changed according to a magnitude of the vehicle-operation load WL of the driver. More specifically, a torque generated as the vehicle-operation load WL (= required steering operation accuracy) of the driver becomes larger becomes larger. On the other hand, a torque generated as the vehicle-operation load WL (= required steering operation accuracy) of the driver becomes smaller becomes smaller. Thereby, the process at step S19 is completed, and the vehicle-operation assistance control process proceeds to a process at step S20.

[0070] In the process at step S20, the steering-system assistance control device 8 implements control for generating the steering torque to a steering wheel. Thereby, the process at step S20 is completed, and a series of vehicle-operation assistance control processes are ended.

[0071] As is obvious from the explanations, according to the vehicle-operation assisting device 20 of the second embodiment of the present invention, the operation-signal prediction circuit 24 calculates the left-and-right direction position and the advancing direction angle of the vehicle after an elapse of 1 second, and the difference calculating circuit 6 calculates the difference between the left-and-right direction position and the advancing direction angle for the target travel path. According to such a configuration, even in a travel environment in which an obstacle is present, it is possible to provide to the driver steering operation assistance that matches a feeling of the driver.

[0072] According to the vehicle-operation assisting device 20 of the second embodiment of the present invention, the vehicle-operation-load estimating device 25 estimates the vehicle-operation load WL of the driver, and the steering-system assistance control device 8 increases the control level of the steering system in proportion to the vehicle-operation load WL. According to such a configuration, the higher the vehicle-operation load WL of the driver, the larger the steering torque, transmitted to the driver, in the steering wheel. Thus, it is possible to provide the driver with the vehicle operation assistance in which a steering operation delay or an unstable steering operation resulting from an excessive driving load is inhibited.

[0073] In the process at step S15, the target-travel-path generating circuit 23 calculates, as the target travel path, the route when traveled by the ideal steering angle S' evaluated by an equation $S'=G\times H\times v$. However, a route when traveled by an ideal steering angle S' evaluated by an equation $S'=G_1\times\xi+G_2\times\xi_2$, for example, can be calculated as the target travel path. The parameter ξ_1 in the equation indicates an angle formed by the current advancing direction of the vehicle A and a position P_1 on the center line Lc after an elapse of 1 second, as shown in Fig. 14. The parameter ξ_2 indicates an angle formed by a tangential line L_p that circumscribes an inner border L_R on a curved route ahead of the vehicle A and the advancing direction of the vehicle A. The parameters G_1 and G_2 in the equation are desirably changed according to the vehicle, the driver, and the travel environment.

Third Embodiment

[0074] With reference to Fig. 15 to Fig. 18, a configuration of a vehicle-operation assisting device according to the third embodiment of the present invention is explained next.

Configuration of vehicle-operation assisting device

[0075] As shown in Fig. 15, a vehicle-operation assisting device 30 according to the third embodiment of the present invention includes a weather determining device 31, a time-zone determining device 32, and a target-travel-point generating/correcting circuit 33, in addition to the vehicle-operation-state detecting device 2, the environment-state detecting device 3, the ideal-steering-signal calculating circuit 5, the difference calculating circuit 6, the operation-precision estimating circuit 7, and the steering-system assistance control device 8 in the vehicle-operation assisting device 10 according to the first embodiment

[0076] The weather determining device 31 corresponds to a weather determining means according to the present invention. The weather determining device 31 includes a rain sensor and an illumination sensor, and determines the weather at a time of driving and operating the vehicle. The time-zone determining device 32 corresponds to a time-zone determining means according to the present invention. The time-zone determining device 32 includes a measuring device such as a clock, and determines a time zone at a time of driving and operating the vehicle. The target-travel-point generating/correcting circuit 33 corresponds to the ideal-control-path generating means according to the present invention. A function of the target-travel-point generating/correcting circuit 33 is realized by a microcomputer mounted on the vehicle executing a control program. The function of the target-

travel-point generating/correcting circuit 33 is described later.

[0077] The vehicle-operation assisting device 30 having such a configuration executes a vehicle-operation-assistance control process shown below to output vehicle-operation assistance control suitable for a state of the vehicle operation of the vehicle by the driver or an environment on a periphery of the vehicle. With reference to a flowchart shown in Fig. 15, an operation of the vehicle-operation assisting device 30 when the vehicle-operation assistance control process is executed is explained below.

Vehicle-operation assistance control process

[0078] The flowchart shown in Fig. 16 is started at a timing at which the ignition switch of the vehicle is switched from an off state to an on state, and the vehicle-operation assistance control process proceeds to a process at step S31. The vehicle-operation assistance control process is executed repeatedly for each predetermined control cycle. The process at step S31 is the same as that at step S 1 shown in Fig. 4, and thus descriptions thereof will be omitted below, and the description is started from a process at step S32.

[0079] In the process at step S32, the weather determining device 31 determines the weather on a periphery of the vehicle, and the time-zone determining device 32 determines a current time zone. More specifically, when a rain drop is detected by the rain sensor, the weather determining device 31 determines that the weather on a periphery of the vehicle is rain. The time-zone determining device 32 determines by segmenting the current time zone into early morning, daytime, evening, and nighttime. Thereby, the process at step S32 is completed, and the vehicle-operation assistance control process proceeds to a process at step S33.

[0080] In the process at step S33, the target-travel-point generating/correcting circuit 33 generates and corrects the target travel location based on a process result at step S32. More specifically, the target-travel-point generating/correcting circuit 33 calculates a lane central position in the vehicle advancing direction as the target travel location at which the vehicle should pass in the future, based on the current vehicle position detected by the process at step S31. Subsequently, when the weather determined by the process at step S32 indicates rain or the time zone determined thereby indicates the nighttime, the target-travel-point generating/correcting circuit 33 corrects the calculated target travel location to the lane central position H1[m] ahead. When the weather is fine and the time zone is early morning or evening, the target-travel-point generating/ correcting circuit 33 corrects the calculated target travel location to the lane central position H2(>H1)[m] ahead. In another case, when the weather is fine and the time zone is daytime, the target-travel-point generating/correcting circuit 33 corrects the calculated target travel location to the lane central position H3 (>H2)[m] ahead. Thereby, the process at step S33 is completed, and the vehicle-operation assistance control process proceeds to a process at step S34.

[0081] In the process at step S34, the ideal-steering-signal calculating circuit 5 calculates the ideal steering angle S to reach the target travel location calculated by the process at step S33. More specifically, the ideal-steering-signal calculating circuit 5 inputs the information detected by the vehicle-operation-state detecting device 2 and the environment state detecting device 3, into a driver model in which a value of the ideal steering angle S is 2-G"-u-(v/L) (v denotes a vehicle speed, and G" denotes a steering gain of the vehicle), where u denotes an angle formed by: a vector connecting the current vehicle position P_0 and the target travel location P; and the vehicle advancing direction thereby to calculate the ideal steering angle S to reach the target travel location calculated by the process at step S33. The steering gain G" is G1 when the weather determined by step S32 is rain or the time zone determined thereby is nighttime; G2 (<G1) when the weather is fine and the time zone is early morning or evening; and G3(<G2) when the weather is fine and the time zone is daytime. Thereby, the process at step S34 is completed, and the vehicle-operation assistance control process proceeds to a process at step S35.

[0082] In the process at step S35, the vehicle-operation-state detecting device 2 detects a current vehicle steering angle S. Thereby, the process at step S35 is completed, and the vehicle-operation assistance control process proceeds to a process at step S36.

[0083] In the process at step S36, the difference calculating circuit 6 calculates a difference δ(=S-S) between: the ideal steering angle S calculated by the process at step S34; and the current vehicle steering angle S detected by the process at step S35. Thereby, the process at step S36 is completed, and the vehicle-operation assistance control process proceeds to a process at step S37.

[0084] In the process at step S37, the operation-precision estimating circuit 7 estimates: the weather on a periphery of the vehicle determined by the process at step S32; and the steering accuracy "a" required in the current time zone. Generally, the steering operation accuracy "a" is correlated with the weather on a periphery of the vehicle, the illumination, and the time zone over which the vehicle travels, as shown in Figs. 17(a), 17(b), and 17(c). Accordingly, in the third embodiment, the operation-precision estimating circuit 7 previously holds maps shown in Figs. 16(a), 16(b), and 16(c), and reads out from the maps the weather on a periphery of the vehicle determined by the process at step S32 and the steering accuracy "a" corresponding to the current time zone to estimate the required steering accuracy "a". Thereby, the process at step S37 is completed, and the vehicle-operation assistance control process proceeds to a process at step S38.

[0085] In the process at step S38, the steering system

assistance control device 8 changes the torque output rule based on: the horizontal direction distance In between the center line Lc of the traffic lane of the vehicle and the traveling position of the vehicle A, detected by the process at step S31; the difference δ between the ideal steering angle S and the current vehicle steering angle S, calculated by the process at step S36; and the steering operation accuracy "a" estimated by the process at step S37. Thereby, the process at step S38 is completed, and the vehicle-operation assistance control process proceeds to a process at step S39.

[0086] In the process at step S39, the steering-system assistance control device 8 implements control for generating the steering torque to a steering wheel. Thereby, the process at step S39 is completed, and a series of vehicle-operation assistance control processes are ended.

[0087] As is obvious from the explanations, according to the vehicle-operation assisting device 30 of the third embodiment of the present invention, the weather determining device 31 determines the weather at a time of the vehicle operation, and the time-zone determining device 32 determines the time zone at a time of the vehicle operation. When the weather determined by the weather determining device 31 is bad and/or the time zone determined by the time-zone determining device 32 is nighttime, the target-travel-point generating/correcting circuit 33 corrects a position of the target travel location according to the determined weather and time zone, and the steering-system assistance control device 8 increases the control level of the steering system. This makes it possible to provide the driver with more stable vehicle operation assistance.

[0088] In the present embodiment, the target-travel-point generating/correcting circuit 33 cakulates one target travel location only at a single process. However, a plurality of target travel locations can be chronologically calculated by the single process. In this case, the target-travel-point generating/correcting circuit 33 can change the number of calculated target travel locations according to the steering accuracy "a" calculated by the process at step S37, as shown in Fig. 17.

Fourth Embodiment

[0089] With reference to Fig. 19 to Fig. 23, a configuration of a vehicle-operation assisting device according to a fourth embodiment of the present invention is explained next.

Configuration of vehicle-operation assisting device

[0090] As shown in Fig. 19, a vehicle-operation assisting device 40 according to the fourth embodiment of the present invention includes a driving-technique estimating device 41, a target-travel-point generating/correcting circuit 42, and an aimless-driving detecting device 43, in addition to the vehicle-operation-state detecting device 2, the environment-state detecting device 3, the difference calculating circuit 6, the steering-system assistance control device 8 in the vehicle-operation assisting device 10 according to the first embodiment, and the operation-signal prediction circuit 24 in the vehick-operation assisting device 20 according to the second embodiment.

[0091] The driving-technique estimating device 41 corresponds to a vehicle-operation-technique estimating means according to the present invention. The driving-technique estimating device 41 utilizes a technique for estimating a driving technique of the driver, which is known by the time of the application of the invention of the subject application, from frequency of modified steerings in the steering operation of the driver to estimate the driving technique of the driver. The target-travel-point generating/correcting circuit 42 corresponds to the ideal-control-path generating means according to the present invention. A function (operation) of the target-travel-point generating/correcting circuit 42 is realized by a microcomputer mounted on the vehicle executing a control program. A function of the target-travel-point generating/correcting circuit 42 is described later. The aimless-driving detecting device 43 corresponds to an aimless-operation-driving detecting means according to the present invention. The aimless-driving detecting device 43 utilizes a technique for detecting an aimless driving, which is known by the time of the application of the invention of the subject application, from a length of a time in which the steering is not implemented in the steering operation of the driver and a generation frequency thereof to estimate an aimless driving of the driver.

[0092] The vehicle-operation assisting device 40 having such a configuration executes a vehicle-operation-assistance control process shown below to output vehicle-operation assistance control suitable for a state of the vehicle operation of the vehicle by the driver or an environment on a periphery of the vehicle. With reference to a flowchart shown in Fig. 19, an operation of the vehicle-operation assisting device 40 when the vehicle-operation assistance control process is executed is explained below.

Vehicle-operation assistance control process

[0093] The flowchart shown in Fig. 20 is started at a timing at which the ignition switch of the vehicle is switched from an off state to an on state, and the vehicle-operation assistance control process proceeds to a process at step S41. The vehicle-operation assistance control process is executed repeatedly for each predetermined control cycle. The processes at steps S41 and S42 are the same as those at steps S11 and S12 shown in Fig. 11, and thus descriptions thereof will be omitted. The description is started from a process at step S43.

[0094] In the process at step S43, the driving-technique estimating device 41 estimates the driving technique of the driver. In the present embodiment, the driving-technique estimating device 41 estimates that the

higher the frequency of the modified steerings detected via the steering angle sensor provided in the vehicle-operation-state detecting device 2, the lower the driving technique of the driver. Thereby, the process at step S43 is completed, and the vehicle-operation assistance control process proceeds to a process at step S44.

[0095] In the process at step S44, the target-travel-point generating/correcting circuit 42 generates and corrects the target travel location based on the driving technique of the driver, estimated by the process at step S43. More specifically, the target-travel-point generating/correcting circuit 42 calculates, as the target travel location, a middle position P_1 of a route width on which the vehicle A can travel when the vehicle A reaches a position of an obstacle O, as shown in Fig. 21. The target-travel-point generating/correcting circuit 42 corrects the position of the target travel location as close as possible to the obstacle O when the driving technique of the driver estimated by the process at step S43 is high. That is, as shown in Fig. 21, when the vehicle A is positioned at the position P_0 offset only by the distance ω from the center of the traffic lane, in order for the vehicle A to reach a position P_1 during a time that the vehicle A travels a distance L0 [m], the vehicle needs to move in right and left directions by a distance $\zeta(=\omega+wo/2)$ only. When the driving technique estimated by the process at step S43 is high, the target-travel-point generating/correcting circuit 42 subtracts a distance σ from the distance ζ in order to obtain the target travel location brought as close as possible to the obstacle, and sets, as an intermediate point to reach from the position P_0 to the position P_1, a position P_2 which is a point at (L0/2, ζ/2) relatively from the position P_0. Thereby, the process at step S44 is completed, and the vehicle-operation assistance control process proceeds to a process at step S45.

[0096] In the process at step S45, the ideal-steering-signal calculating circuit 5 calculates the ideal steering angle S to reach the target travel location calculated by the process at step S44. More specifically, the ideal-steeringsignal calculating circuit 5 inputs the information detected by the vehicle-operation-state detecting device 2 and the environment-state detecting device 3, into a driver model in which the value of the ideal steering angle S is $G\times IL0/2)\times(\zeta/2)$ (G denotes a steering gain of the vehicle) during a time that the vehicle A is moving from the position P_0 to the position P_2, or into a driver model in which the value of the ideal steering angle S is $-G\times(L0/2)\times(\zeta/2)$ during a time that the vehicle A is moving from the position P_2 to the position P_1, whereby the ideal steering angle S to reach the target travel location calculated by the process at step S44 is calculated. Thereby, the process at step S44 is completed, and the vehicle-operation assistance control process proceeds to a process at step S45.

[0097] In the process at step S46, the operation-signal prediction circuit 24 utilizes the information detected by the vehicle-operetion-state detecting device 2 to calculate a left-and-right direction position and an advancing direction angle of the vehicle after an elapse of 1 second. This process is the same as that at step S16 shown in Fig. 11, and thus detailed descriptions thereof will be omitted. Thereby, the process at step S46 is completed, and the vehicle-operation assistance control process proceeds to a process at step S47.

[0098] In the process at step S47, the difference calculating circuit 6 calculates a difference between the left-and-right direction position and the advancing direction angle calculated by the process at step S46 for the ideal steering angle S calculated by the process at step S45. This process is the same as that at step S17 shown in Fig. 10, and thus detailed descriptions thereof will be omitted. Thereby, the process at step S47 is completed, and the vehicle-operation assistance control process proceeds to a process at step S48.

[0099] In the process at step S48, the aimless-driving detecting device 43 determines whether the driver perform the aimless driving. More specifically, the aimless-driving detecting device 43 determines that the driver performs the aimless driving when the frequency of steerings detected via the steering angle sensor provided in the vehicle-operation-state detecting device 2 is small. Thereby, the process at step S48 is completed, and the vehicle-operation assistance control process proceeds to a process at step S49.

[0100] In the process at step S49, the steering-system assistance control device 8 changes the torque output rule based on a result of a determination process at step S48. In the present embodiment, the torque output rule is that in a power-assist mechanism for generating a torque in proportion to a magnitude of the difference δ between the ideal steering angle S and current steering angle S of the vehicle, as indicated by a solid line L_1 in Fig. 22. The torque T can be expressed as $T=K\times\delta$, where K denotes a constant of proportion. When the aimless driving of the driver is detected, the torque output rule is changed as indicated by a dotted line L2 in which the constant of proportion shown in Fig. 22 is larger than the constant of proportion K, and as a result, a torque larger than usual is outputted. Thereby, the process at step S49 is completed, and the vehicle-operation assistance control process proceeds to a process at step S50.

[0101] In the process at step S50, the steering-system assistance control device 8 implements control for generating the steering torque to a steering wheel. Thereby, the process at step S50 is completed, and a series of vehicle-operation assistance control processes are ended.

[0102] As is obvious from the explanations, according to the vehicle-operation assisting device 40 of the fourth embodiment of the present invention, the driving-technique estimating device 41 estimates the driving technique of the driver. When the driving technique of the driver is low, the target-travel-point generating/correcting circuit 42 corrects the target travel location, and the steering-system assistance control device 8 increases the control level of the steering system. Thus, the target travel

location generated for guiding and assisting the driver can be corrected to that suits the driving technique of the driver, and as a result, it becomes possible to provide the driver with vehicle operation assistance by the target travel path that suits the technique of the driver.

[0103] According to the vehicle-operation assisting device 40 of the fourth embodiment of the present invention, when the aimless driving of the driver is detected by the aimless-driving detecting device 43, the steering-system assistance control device 8 increases the steering torque in the steering wheel transmitted to the driver, and thus, it is possible to provide the driver with vehicle operation assistance in which a steering delay or an unstable steering resulting from the aimless driving is inhibited. In the process at step S44, the distance L_0 is a fixed value. However, as shown in Fig. 22, the distance Lo can be changed according to a magnitude of the driving technique of the driver.

Fifth Embodiment

[0104] Last, with reference to Fig. 24 to Fig. 26, a configuration of a vehicle-operation assisting device according to the fifth embodiment of the present invention is explained.

Configuration of vehicle-operation assisting device

[0105] As shown in Fig. 24, a vehicle-operation assisting device 50 according to the fifth embodiment of the present invention includes a lane-change-intention estimating device 51, a merging-intention determining device 52, and a steering-history storage circuit 53 in addition to the vehicle-operation-state detecting device 2, the environment-state detecting device 3, the difference calculating circuit 6, and the steering-system assistance control device 8 in the vehicle-operation assisting device 10 according to the first embodiment, and the target-travel-path generating circuit 23 and the operation-signal prediction circuit 24 in the vehicle-operation assisting device 20 according to the second embodiment.

[0106] The lane-change-intention estimating device 51 corresponds to a lane-change-intention estimating means according to the present invention. The lane-change-intention estimating device 51 uses a pattern matching method known by the time of the application of the invention of the subject application to estimate an inter-vehicular distance from a preceding vehicle traveling ahead of the vehicle or a relative speed, and utilizes a technique to estimate a traffic-lane-change intention of the driver from a turning ON/OFF of a turning signal to estimate the traffic-lane-change intention of the driver.

[0107] The merging-intention determining device 52 corresponds to a merging-intention estimating means according to the present invention. The merging-intention determining device 52 includes a navigation device, and determines that the driver intends to merge when the vehicle travels on a merging traffic lane and turns on the turning signal. The steering-history storage circuit 53 corresponds to a steering-angle history storage means according to the present invention. The steering-histvry storage circuit 53 is configured by a non-volatile storage device such as a ROM, and stores a chronological change of the steering angle at a time of a past traffic lane change or merging.

[0108] The vehicle-operation assisting device 50 having such a configuration executes a vehicle-operation-assistance control process shown below to output vehicle-operation assistance control suitable for a state of the vehicle operation of the vehicle by the driver or an environment on a periphery of the vehicle. With reference to a flowchart shown in Fig. 24, an operation of the vehicle-operation assisting device 50 when the vehicle-operation assistance control process is executed is explained below.

Vehicle-operation assistance control process

[0109] The flowchart shown in Fig. 25 is started at a timing at which the ignition switch of the vehicle is switched from an off state to an on state, and the vehicle-operation assistance control process proceeds to a process at step S61. The vehicle-operation assistance control process is executed repeatedly for each predetermined control cycle. The process at step S61 is the same as that at step S11 shown in Fig. 4, and thus descriptions thereof will be omitted below, and the description is started from a process at step S62.

[0110] In the process at step S62, the lane-change-intention estimating device 51 determines whether the driver has the traffic-lane change intention. When a result of the determination indicates that the driver has the traffic-lane-change intention, the lane-change-intention estimating device 51 proceeds the vehicle-operation assistance controls process to a process at step S65. On the other hand, when the driver does not have the traffic-lane-change intention, the lane-change-intention estimating device 51 proceeds the vehicle-operation assistance control process to a process at step S63.

[0111] In the process at step S63, the merging-intention determining device 52 determines whether the driver intends to merge onto a merged traffic lane. When a result of the determination indicates that the driver has a merging intention, the merging-intention determining device 52 proceeds the vehicle-operation assistance control process to a process at step S65. On the other hand, when the driver does not have the merging intention, the merging-intention determining device 52 proceeds the vehicle-operation assistance control process to a process at step S64.

[0112] In the process at step S64, the environment-state detecting device 3 detects a degree of congestion of a lane adjacent to the lane on which the vehicle travels. More specifically, the environment-state detecting device 3 utilizes a laser radar or an ultrasonic sensor to detect

whether a vehicle is present on the lane adjacent to the lane on which the vehicle travels, and detects the number of vehicles to be detected within a predetermined time as the degree of congestion. Thereby, the process at step S64 is completed, and the vehicle-operation assistance control process proceeds to a process at step S67.

[0113] In the process at step S65, the environment-state detecting device 3 detects a degree of congestion on an entered lane onto which the vehicle is about to enter. More specifically, the environment-state detecting device 3 utilizes a laser radar or an ultrasonic sensor to detect whether a vehicle is present on the entered lane, and detects the number of vehicles to be detected within a predetermined time as the degree of congestion. Thereby, the process at step S65 is completed, and the vehicle-operation assistance control process proceeds to a process at step S66.

[0114] In the process at step S66, the target-travel-path generating circuit 23 obtains information about a chronological change of the steering angle at a time of the past lane change or merging stored in the steering-history storage circuit 53. Generally, when changing the lane or merging, the driver performs the steering operation by a fixed chronological change. Accordingly, in the fifth embodiment, the steering history storage circuit 53 holds therein, as the steering history, the chronological change of the steering angle at a time of the past lane change or merging, and the target-travel-path generating circuit 23 obtains, as the steering history, the relevant chronological change of the steering angle, as needed. Thereby, the process at step S66 is completed, and the vehicle-operation assistance control process proceeds to a process at step S67.

[0115] In the process at step S67, the target-travel-path generating circuit 23 generates the target travel paths, i.e., a target travel path when the lane change and the merging intention are not detected; and that when at least one of the lane change and the merging intention is detected. More specifically, when the lane change and the merging intention are not detected, the target-travel-path generating circuit 23 generates, as the target travel path, a route traveled by the ideal steering angle $S=G\times I\times v$, where T denotes a central point of the traffic lane at a position H[m] ahead of the vehicle and u denotes an angle formed by a vector connecting the current vehicle position and the central point T and the vehicle advancing direction. On the other hand, when at least one of the lane change and the merging intention is detected, the target-travel-path generating circuit 23 generates, as the target travel path, a route traveled by the past steering history obtained by the process at step S66. Thereby, the process at step S67 is completed, and the vehicle-operation assistance control process proceeds to a process at step S68.

[0116] In the process at step S68, the operation-signal prediction circuit 24 utilizes the information detected by the vehicle-operation-state detecting device 2 to calculate a left-and-right direction position and an advancing direction angle of the vehicle within the route after an elapse of 1 second. This process is the same as that at step S16 shown in Fig. 11, and thus detailed descriptions thereof will be omitted. Thereby, the process at step S68 is completed, and the vehicte-operation assistance control process proceeds to a process at step S69.

[0117] In the process at step S69, the difference calculating circuit 6 calculates a difference between the left-and-right direction position and the advancing direction angle calculated by the process at step S46 for the ideal steering angle S generated by the process at step S67. This process is the same as that at step S17 shown in FSg. 11, and thus detailed descriptions thereof will be omitted. Thereby, the process at step S69 is completed, and the vehicle-operation assistance control process proceeds to a process at step S70.

[0118] In the process at step S70, the steering-system assistance control device 8 changes the torque output rule based on the degree of congestion detected by the processes at steps S64 and S65. The torque output rule in the fifth embodiment, as indicated by a solid line L_1 in Fig. 26, is an output rule in a power-assist mechanism for generating a torque in proportion to a magnitude of the difference δ calculated by the process at step S69, and a torque T can be expressed as $T=K\times\delta$, where K denotes a constant of proportion. The constant of proportion K becomes larger as the degree of congestion become larger, and the torque output rule is changed as indicated by a dotted line L2 in Fig. 25. On the other hand, the constant of proportion K becomes smaller as the degree of congestion becomes smaller, and the torque output rule is changed as indicated by a dotted line L3 in Fig. 25. Thereby, the process at step S70 is completed, and the vehicle-operation assistance control process proceeds to a process at step S71.

[0119] In the process at step S71, the steering-system assistance control device 8 implements control for generating the steering torque to a steering wheel. Thereby, the process at step S71 is completed, and a series of vehicle-operation assistance control processes are ended.

[0120] As is obvious from the explanations, according to the vehicle-operation assisting device 50 of the fifth embodiment of the present invention, the environment-state detecting device 3 detects the degree of congestion on the lane adjacent to the lane on which the vehicle travels and the entered lane on which the vehicle is about to enter, and the steering-system assistance control device 8 increases the control level of the steering system as the degree of congestion becomes larger. Thus, even in a situation with a high possibility of generating an unstable steering by the driver, the assistance to stabilize the steering operation can be provided to the driver.

[0121] According to the vehicle-operation assisting device 50 of the fifth embodiment of the present invention, when the lane change intention or the merging intention of the driver is estimated, the target-travel-path generating circuit 23 generates, as the target travel path, the

route traveled based on the past steering history, and thus, even in a steering situation with a large deviance between the drivers, it is possible to provide vehicle operation assistance that matches the feeling of the driver.

Industrial Applicability

[0122] The present invention can be applied to a technique of assisting an operators control operation of a control object.

Claims

1. A control-operation assisting device that assists control operation of an operator on a manipulator (112) for control of a controlled object (114), comprising:

a controlled-object-state detection unit (102) that detects information about the state of the controlled object (114);
a manipulator-state detection unit (113) that detects information about the state of manipulator (112);
an environment-state detection unit (101) that detects information about the state of control operation environment on the periphery of the controlled object (114);
an actuator-torque-controller-assistance system (109) that controls additional torque produced by an actuator (111), **characterized by**
an ideal-interaction generating unit (103) that generates the ideal interaction dynamics between the controlled object (114) and the environment from the information about the state of the controlled object (114) detected by the controlled-object-state detection unit (102) and the environmental state detected by the environment-state detection unit (101);
an ideal-manipulator-impedance generating unit (106) that generates an ideal impedance for the manipulator (112) from the ideal interaction dynamics between controlled object (114) and the environment generated by the ideal-interaction generating unit (103);
a manipulator-impedance-controller assistance system (110) that controls the impedance of the manipulator (112) based on the ideal manipulator impedance generated by the ideal-manipulator-impedance generating unit (106) to produce the desired interaction dynamics between the controlled object (114) and the environment;
an ideal-manipulator-control-signal generating unit (104) that generates an ideal-manipulator-control-signal from the ideal interaction dynamics between controlled object (114) and the environment generated by the ideal-interaction generating unit (103);
a manipulator-control-signal-difference calculating unit (107) that calculates the difference between the ideal-manipulator-control-signal generated by the ideal-manipulator-control-signal generating unit (104) and the state of the manipulator (112) detected by the manipulator-state detection unit (113);
an operation-precision estimation unit (105) that estimates a precision required for the control operation of the controlled object (114) from the ideal interaction dynamics between the controlled object (114) and the environment generated by the ideal-interaction generating unit (103);
a control-difference-impedance generating unit (108) that generates a control difference impedance from the required precision estimated by the operation-precision estimation unit (105); wherein
the actuator-torque-controller-assistance system (109) controls the additional torque produced by the actuator (111) based on the magnitude of the difference calculated by the manipulator-control-signal-difference calculating unit (107) and the control difference impedance calculated by the control-difference-impedance generating unit (108) to assist the control-operation of the operator on the manipulator (112) to achieve the required operation precision.

2. A control-operation assisting device according to claim 1, **characterized by** an ideal-control-path generating unit that generates an ideal control path for the controlled object (114) from the information about the state of the controlled object (114) detected by the controlled-object-state detection unit (102) and the environmental state detected by the environment-state detection unit (101).

3. A control-operation assisting device according to claim 2, **characterized by** an ideal-manipulator-control-signal generation unit that generates, as the ideal-manipulator-control-signal, a control signal profile to control the controlled object (114) to travel along the ideal control path generated by the ideal-control-path generating unit.

4. A control-operation assisting device according to claim 3, **characterized by** a control-signal prediction unit that predicts information about the control operation state up to a predetermined future time, based on the information about the state of the controlled object (114) detected by the controlled-object-state detection unit (102), wherein the manipulator-control-signal-difference-calculating unit (107) calculates the difference between the ideal-manipulator-control-signal, up to a predetermined future time, generated by the ideal-manipulator-control-signal generation unit and the information about the control

operation state, up to a predetermined future time, predicted by the control-signal prediction unit.

5. A control-operation assisting device according to claim 3 or 4, **characterized in that** the ideal-manipulator-control-signal generating calculating unit (104) uses an operator model for calculating the ideal-manipulator-control-signal from the information about the state of the controlled object (114) detected by the controlled-object-state detection unit (102) and the information about the state of control operation environment detected by the environment-state detection unit (101).

6. A control-operation assisting device according to any one of claims 1 to 5, **characterized in that** the controlled-object-state detection unit (102) detects, as the information about the state of the controlled object (114), at least one of the orientation of the controlled object (114), the speed thereof, the advancing direction angle thereof, the acceleration thereof, and the manipulator value thereof.

7. A control-operation assisting device according to any one of claims 1 to 6, **characterized in that** the environment-state detection unit (101) detects, as the information about the state of control operation environment, at least one of: obstacles present on a periphery of the controlled object (114); a curve-linear barrier, a width, a roughness along the path along which the controlled object (114) travels; and moving bodies adjacent to the control led object.

8. A control-operation assisting device according to any one of claims 1 to 7, **characterized in that** the actuator-torque-controller-assistance system (109) adapts the force output rule of the controlled object (114) to control the controlled object (114) and controls the level of force added to the control operation on the manipulator (112) of the operator, written as the force output rule, to control the assistance level of the control operation.

9. A control-operation assisting device according to claim 8, **characterized in that** the actuator-torque-controller-assistance system (109) adapts the force output rule of the controlled object (114) to control the controlled object (114), written as the force output rule, to control the assistance level of the control operation.

10. A control-operation assisting device according to claim 8, **characterized in that** the actuator-torque-controller-assistance system (109) controls the level of force added to the control operation on the manipulator (112) of the operator to control the assistance level of the control operation.

11. A control-operation assisting device according to any one of claims 1 to 10, **characterized by** a control-operation-load estimating unit that estimates the control-operation load of the operator, wherein the actuator-torque-controller-assistance system (109) increases the assistance level of the control operation as the control-operation load estimated by the control-operation-load estimating unit becomes larger.

12. A control-operation assisting device according to any one of claims 8 to 11, **characterized in that** the force output rule is a torque output rule of the actuator (111).

13. A control-operation assisting device according to claim 12, **characterized in that** the actuator-torque-controller-assistance system (109) changes the torque output rule according to the control difference impedance generated by the control-difference-impedance generating unit (108).

14. A control-operation assisting device according to any one of claims 1 to 13, **characterized by**:

a movable-region calculating unit that calculates a width of the region in which the controlled object (114) can move, from the information about the state of control operation environment detected by the environment-state detection unit (101); and

an approximate-control-region calculating unit that approximates the movable region calculated by the movable-region calculating unit by a plurality of curved regions and straight regions, wherein

when the environment-state detection unit (101) detects an obstacle on the periphery of the controlled object (114), the ideal-interaction generating unit (103) generates an ideal interaction path within the region approximated by the approximate-control-region calculating unit.

15. A control-operation assisting device according to any one of claims 1 to 14, **characterized by** a control-operation-technique estimating unit that estimates a control-operation technique of the operator, wherein the control-operation-technique estimating unit estimates that the higher a frequency of modified steerings detected via a steering angle sensor provided in the vehicle-operation-state detection unit (102), the lower the driving technique of the operator, and the actuator-torque-controller-assistance system (109) increases the control level of the control operation as the control operation technique of the operator estimated by the control-operation-technique estimating unit becomes smaller.

16. A control-operation assisting device according to claim 14 or 15, **characterized by** a control condition determining unit that determines control condition at a time of the control operation and/or a time-zone determining unit that determines the time zone at a time of the control operation, wherein when the control condition determined by the control condition determining unit is bad and/or when the time zone determined by the time-zone determining unit is nighttime, the ideal-interaction generating unit (103) adapts the generated ideal control path and the actuator-torque-controller-assistance system (109) increases the assistance level of the control operation.

17. A control-operation assisting device according to any one of claims 14 to 16, **characterized by** a degraded-operation detection unit that detects degraded operation of the operator, wherein when the degraded operation of the operator is detected by the degraded-operation detection unit, the ideal-interaction generating unit (103) corrects the generated ideal control path, and the actuator-torque-controller-assistance system (109) increases the assistance level of the control operation.

18. A control-operation assisting device according to any one of claims 1 to 17, **characterized in that** the actuator-torque-controller-assistance system (109) increases the assistance level of the control operation as the number of moving bodies, adjacent to the controlled object (114), detected by the environment-state detection unit (101) becomes larger.

19. A control-operation assisting device according to any one of claims 1 to 18, **characterized in that** the controlled object (114) is a vehicle, the device comprises a lane-change-intention estimating unit that estimates a lane change intention of the operator; and a first steering-angle profile storage unit that stores information about a chronological change of a steering angle of a vehicle detected by the controlled-object-state detection unit (102) at the time of past lane changes, and when the lane change intention of the operator is estimated by the lane-change-intention estimating unit, the ideal-manipulator-control-signal generating unit (104) references the information about the chronological change of the steering angle of the vehicle, stored in the first steering-angle profile storage unit, to generate a steering profile of the vehicle at a time of the past lane change, as the ideal-manipulator-control-signal.

20. A control-operation assisting device according to claim 19, **characterized by**:

a merging-intention estimating unit that estimates the merging intention of the operator; and
a second steering-angle profile storage unit that stores information about the chronological changes of a steering angle detected by the controlled-object-state detection unit (102) at the time of past merging, wherein
when the merging intention of the operator is estimated by the merging-intention estimating unit, the ideal-manipulator-control-signal generating unit (104) references the information about the chronological change of the steering angle of the vehicle, stored in the second steering-angle profile storage unit, to generate a steering profile of the vehicle at the time of past merging, as the ideal-manipulator-control-signal, and when the environment-state detection unit (101) detects a predetermined number or more of vehicles traveling on a merged lane the actuator-torque-controller-assistance system (109) increases the assistance level of the control operation.

21. A control-operation assisting method for assisting the control operation of an operator for control of a control controlled object (114), comprising:

a step of generating an ideal control path of the control controlled object (114) from information about the control operation state of the operator and
information about the control operation environment on the periphery of the control controlled object (114);
a step of calculating, as an ideal control signal, a control profile of an operation system for the control controlled object (114) to operate along the generated ideal control path;
a step of calculating the difference between the calculated ideal control signal and the information about the control operation state;
a step of controlling the operation system based on the magnitude of the calculated difference to assist the operation of the operator for the operation system; and
a step of estimating the accuracy required for the control operation of the control controlled object (114), from the information about the control operation state and/or the information about the control operation environment, wherein
at step of assisting the operation of the operator, the assistance level of the operation system is increased as the estimated accuracy becomes higher.

Patentansprüche

1. Steuerungsbetätigung- unterstützende Vorrichtung, die die Steuerungsbetätigung einer Bedienperson an einem Manipulator (112) zum Steuern eines ge-

steuerten Objektes (114) unterstützt, aufweisend:

eine Zustandserfassungseinheit (102) für ein gesteuertes Objekt, die eine Information über den Zustand des gesteuerten Objektes (114) erfasst;
eine Zustandserfassungseinheit (113) für einen Manipulator, die eine Information über den Zustand des Manipulators (112) erfasst;
eine Zustandserfassungseinheit (101) für eine Umgebung, die eine Information über den Zustand der Steuerungsbetätigungsumgebung an der Peripherie des gesteuerten Objektes (114) erfasst;
ein Betätigerdrehmoment- Steuerungsunterstützungssystem (109), das ein zusätzliches Drehmoment, erzeugt durch einen Betätiger (111), steuert, **gekennzeichnet durch**
eine Erzeugungseinheit (103) für eine ideale Interaktion, die die ideale Interaktionsdynamiken zwischen dem gesteuerten Objekt (114) und der Umgebung aus der Information über den Zustand des gesteuerten Objektes (114), erfasst **durch** die Zustandserfassungseinheit (102) für das gesteuerte Objekt, und dem Umgebungszustand, erfasst **durch** die Zustandserfassungseinheit (101) für eine Umgebung,
erzeugt;
eine ideale- Manipulatorimpedanz-Erzeugungseinheit (106), die eine ideale Impedanz für den Manipulator (112) aus den idealen Interaktionsdynamiken zwischen dem gesteuerten Objekt (114) und der Umgebung, erzeugt **durch** die Erzeugungseinheit (103) für eine ideale Interaktion, erzeugt;
ein Manipulatorimpedanz- Steuerungs-Unterstützungssystem (110), das die Impedanz des Manipulators (112) auf der Grundlage der idealen Manipulatorimpedanz, erzeugt **durch** die Impedanzerzeugungseinheit (106) für den idealen Manipulator, steuert, um die gewünschten Interaktionsdynamiken zwischen dem gesteuerten Objekt (114) und der Umgebung zu erzeugen;
eine Steuerungssignal- Erzeugungseinheit (104) für einen idealen Manipulator, die ein idealer- Manipulator- Steuerungssignal aus den idealen Interaktionsdynamiken zwischen dem gesteuerten Objekt (114) und der Umgebung, erzeugt **durch** die Erzeugungseinheit (103) für eine ideale Interaktion, erzeugt;
eine Manipulatorsteuerungssignaldifferenz-Berechnungseinheit (107), die die Differenz zwischen dem idealer- Manipulator- Steuerungssignal, erzeugt **durch** die Steuerungssignal- Erzeugungseinheit (104) für den idealen Manipulator, und den Zustand des Manipulators (112), erfasst **durch** die Manipulator- Zustandserfassungseinheit (113), berechnet;
eine Betätigungsgenauigkeit- Abschätzungseinheit (105), die eine Genauigkeit, erforderlich für den Steuerbetrieb des gesteuerten Objektes (114), aus den idealen Interaktionsdynamiken zwischen dem gesteuerten Objekt (114) und der Umgebung, erzeugt **durch** die Erzeugungseinheit (103) für die ideale Interaktion, abschätzt;
eine Steuerungsdifferenzimpedanz-Erzeugungseinheit (108), die eine Steuerungsdifferenzimpedanz aus der erforderlichen Genauigkeit, abgeschätzt aus der Betätigungsgenauigkeit- Abschätzungseinheit (105), erzeugt; wobei das Betätigerdrehmoment- Steuerungs-Unterstützungssystem (109) das zusätzliche Drehmoment, erzeugt **durch** den Betätiger (111) auf der Grundlage der Größe der Differenz, errechnet **durch** die Manipulatorsteuerungssignaldifferenz-Berechnungseinheit (107), und der Steuerungsdifferenzimpedanz, berechnet **durch** die Steuerungsdifferenzimpedanz-Erzeugungseinheit (108), steuert, um den Steuerungsbetrieb der Bedienperson an dem Manipulator (112) zu unterstützen, um die erforderliche Betätigungsgenauigkeit zu erreichen.

2. Steuerungsbetätigung- unterstützende Vorrichtung nach Anspruch 1, **gekennzeichnet durch** eine Erzeugungseinheit für einen idealen Steuerungspfad, die einen idealen Steuerungspfad für das gesteuerte Objekt (114) aus der Information erzeugt über den Zustand des gesteuerten Objektes (114), erfasst **durch** die Zustandserfassungseinheit (102) für das gesteuerte Objekt, und dem Umgebungszustand, erfasst **durch** die Umgebungszustands-Erfassungseinheit (101).

3. Steuerungsbetätigung- unterstützende Vorrichtung nach Anspruch 2, **gekennzeichnet durch** eine Steuerungssignal- Erzeugungseinheit für den idealen Manipulator, die, als das ideal- Manipulator-Steuerungssignal, eine Steuerungssignalprofil erzeugt, um das gesteuerte Objekt (114) zu steuern, um sich entlang des idealen Steuerungspfades, erzeugt **durch** die ideal- Steuerungspfad- Erzeugungseinheit, zu bewegen.

4. Steuerungsbetätigung- unterstützende Vorrichtung nach Anspruch 3, **gekennzeichnet durch** eine Steuerungssignal-Vorhersageeinheit, die eine Information über den Steuerungsbetätigungszustand bis zu einer vorbestimmten Zukunftszeit auf der Grundlage der Information über den Zustand des gesteuerten Objektes (114), erfasst **durch** die Zustandserfassungseinheit (102) für das gesteuerte Objekt, vorhersagt, wobei die Manipulator- Steuerungssignaldifferenzberechnungseinheit (107) die Differenz berechnet zwischen dem Steuerungssignal für den

idealen Manipulator bis zu einer vorbestimmten Zukunftszeit, erzeugt **durch** die Steuerungssignal- Erzeugungseinheit für den idealen Manipulator und der Information über den Steuerungsbetätigungszustand, bis zu einer vorbestimmten Zukunftszeit, vorbestimmt **durch** die Steuerungssignal-Vorhersageeinheit.

5. Steuerungsbetätigung- unterstützende Vorrichtung nach Anspruch 3 oder 4, **dadurch gekennzeichnet, dass** die Steuerungssignal- Erzeugungseinheit (104) für den idealen Manipulator ein Bedienpersonalmodell verwendet zum Berechnen des Steuerungssignales für den idealen Manipulator aus der Information über den Zustand des gesteuerten Objektes (114), erfasst durch die Zustandserfassungseinheit (102) für das gesteuerte Objekt und der Information über den Zustand der Steuerungsbetätigungsumgebung, erfasst durch die Umgebungs- Zustandserfassungseinheit (101).

6. Steuerungsbetätigung- unterstützende Vorrichtung nach einem der Ansprüche 1 bis 5, **dadurch gekennzeichnet, dass** die Zustandserfassungseinheit (102) für das gesteuerte Objekt als eine Information über den Zustand des gesteuerten Objektes (114) zumindest einen erfasst von der Ausrichtung des gesteuerten Objektes (114), der Geschwindigkeit desselben, dem Vorwärtsrichtungswinkel desselben, der Beschleunigung desselben und den Manipulatorwert derselben.

7. Steuerungsbetätigung- unterstützende Vorrichtung nach einem der Ansprüche 1 bis 6, **dadurch gekennzeichnet, dass** die Umgebungs- Zustandserfassungseinheit (101) als die Information über den Zustand der Steuerungsbetätigungsumgebung zumindest eines erfasst von:

Hindernissen, vorhanden an einer Peripherie des gesteuerten Objektes (114); eine gekrümmte- lineare Barriere, eine Breite, eine Rauhigkeit entlang des Pfades, entlang sich das gesteuerte Objekt (114) bewegt; und sich bewegende Körper, benachbart zu dem steuergeführten Objekt.

8. Steuerungsbetätigung- unterstützende Vorrichtung nach einem der Ansprüche 1 bis 7, **dadurch gekennzeichnet, dass** das Betätigerdrehmoment-Steuerungsunterstützungssystem (109) die Kraftabgaberegel des gesteuerten Objektes (114), angepasst, um das gesteuerte Objekt (114) zu steuern, und das Kraftniveau steuert, hinzugefügt zu der Steuerungsbetätigung an dem Manipulator (112) der Bedienperson, geschrieben als die Kraftabgaberegel, um das Unterstützungsniveau der Steuerungsbetätigung zu steuern.

9. Steuerungsbetätigung- unterstützende Vorrichtung nach Anspruch 8, **dadurch gekennzeichnet, dass** das Betätigerdrehmoment- Steuerungsunterstützungssystem (109) die Kraftabgaberegel des gesteuerten Objektes (114), geschrieben als eine Kraftabgaberegel, angepaßt, um das gesteuerte Objekt (114) zu steuern, um das Unterstützungsniveau der Steuerungsbetätigung zu steuern.

10. Steuerungsbetätigung- unterstützende Vorrichtung nach Anspruch 8, **dadurch gekennzeichnet, dass** das Betätigerdrehmoment- Steuerungsunterstützungssystem (109) das Kraftniveau, hinzugefügt zu der Steuerungsbetätigung an dem Manipulator (112) der Bedienerperson steuert, um das Unterstützungsniveau der Steuerungsbetätigung zu steuern.

11. Steuerungsbetätigung- unterstützende Vorrichtung nach einem der Ansprüche 1 bis 10, **gekennzeichnet durch** eine Steuerungsbetätigungslast- Abschätzungseinheit, die die Steuerungsbetätigungslast der Bedienperson abschätzt, wobei das Betätigerdrehmoment- Steuerungsunterstützungssystem (109) das Unterstützungsniveau der Steuerungsbetätigung erhöht, wenn die Steuerungsbetätigungslast, abgeschätzt **durch** die Steuerungsbetriebslast-Abschätzungseinheit, größer wird.

12. Steuerungsbetätigung- unterstützende Vorrichtung nach einem der Ansprüche 8 bis 11, **dadurch gekennzeichnet, dass** die Kraftabgaberegel eine Drehmomentausgaberegel des Betätigers (111) ist.

13. Steuerungsbetätigung- unterstützende Vorrichtung nach Anspruch 12, **dadurch gekennzeichnet, dass** das Betätigerdrehmoment- Steuerungsunterstützungssystem (109) die Drehmomentausgaberegel entsprechend einer Steuerungsdifferenzimpedanz, erzeugt durch die Steuerungsdifferenzimpedanz-Erzeugungseinheit (108), verändert.

14. Steuerungsbetätigung- unterstützende Vorrichtung nach einem der Ansprüche 1 bis 13, **gekennzeichnet durch**:

eine Berechnungseinheit für einen bewegbaren Bereich, die eine Breite des Bereichs, in dem sich das gesteuerte Objekt (114) bewegen kann, aus der Information über den Zustand der Steuerungsbetätigungsumgebung, erfasst **durch** die Umgebungs- Zustandserfassungseinheit (101), berechnet; und
eine Berechnungseinheit für einen ungefähren Steuerungsbereich, die den bewegbaren Bereich, berechnet **durch** die Berechnungseinheit für den ungefähren Bereich, **durch** eine Mehrzahl von gekrümmten Bereichen und geraden Bereichen annähert, wobei

wenn die Umgebungs- Zustandserfassungseinheit (101) ein Hindernis an der Peripherie des gesteuerten Objektes (114) erfasst, die Erzeugungseinheit (103) für eine ideale Interaktion einen idealen Interaktionspfad innerhalb des Bereiches, angenähert **durch** die Berechnungseinheit für den ungefähren Steuerungsbereich, erzeugt.

15. Steuerungsbetätigung- unterstützende Vorrichtung nach einem der Ansprüche 1 bis 14, **gekennzeichnet durch** eine Steuerungsbetätigungstechnik- Abschätzungseinheit, die eine Steuerungsbetätigungstechnik der Bedienperson abschätzt, wobei die Steuerungsbetätigungstechnik- Abschätzungseinheit abschätzt, dass je höher eine Frequenz der modifizierten Steuerungen, erfasst über einen Steuerwinkelsensor, angeordnet in der Zustandserfassungseinheit (102) für das gesteuerte Objekt, je niedriger die Antriebstechnik der Bedienperson und das Betätigerdrehmoment- Steuerungsunterstützungssystem (109) erhöht das Steuerungsniveau der Steuerungsbetätigung, wenn die Steuerungsbetätigungstechnik der Bedienperson, abgeschätzt **durch** die Steuerungsbetätigungstechnik- Abschätzungseinheit, kleiner wird.

16. Steuerungsbetätigung- unterstützende Vorrichtung nach Anspruch 14 oder 15, **gekennzeichnet durch** eine Steuerungszustand- Feststellungseinheit, die den Steuerungszustand zu einer Zeit des Steuerungsbetätigung bestimmt und / oder eine Zeitzonen- Feststellungseinheit, die die Zeitzone zu einer Zeit der Steuerungsbetätigung feststellt, wobei, wenn der Steuerungszustand, festgestellt **durch** die Steuerungszustand- Feststellungseinheit, schlecht ist und / oder, wenn die Zeitzone, festgestellt **durch** die Zeitzonen- Feststellungseinheit, eine Nachtzeit ist, die Erzeugungseinheit (103) für eine ideale Interaktion den erzeugten idealen Steuerungspfad anwendet und das Betätigerdrehmoment- Steuerungsunterstützungssystem (109) das Unterstützungsniveau des Steuerungsbetriebs erhöht.

17. Steuerungsbetätigung- unterstützende Vorrichtung nach einem der Ansprüche 1 bis 16, **gekennzeichnet durch** eine Erfassungseinheit für eine beeinträchtigte Betätigung, die einen verminderten Betätigung der Betriebsperson erfasst, wobei dann, wenn die verminderte Betätigung der Bedienperson **durch** die Erfassungseinheit für die beeinträchtigte Betätigung erfasst wird, die Erzeugungseinheit (103) für eine ideale Interaktion den erzeugten idealen Steuerungspfad korrigiert und das Betätigerdrehmoment-Steuerungsunterstützungssystem (109) das Unterstützungsniveau der Steuerungsbetätigung erhöht.

18. Steuerungsbetätigung- unterstützende Vorrichtung nach einem der Ansprüche 1 bis 17, **dadurch gekennzeichnet, dass** das Betätigerdrehmoment-Steuerungsunterstützungssystem (109) das Unterstützungsniveau der Steuerungsbetätigung erhöht, wenn die Anzahl der sich bewegenden Körper, benachbart zu dem gesteuerten Objekt (114), erfasst durch die Umgebungs- Zustandserfassungseinheit (101), größer wird.

19. Steuerungsbetätigung unterstützende Vorrichtung nach einem der Ansprüche 1 bis 18, **dadurch gekennzeichnet, dass** das gesteuerte Objekt (114) ein Fahrzeug ist, wobei die Vorrichtung aufweist eine Spurveränderungsabsicht- Abschätzungseinheit, die eine Spurveränderungsabsicht der Bedienperson abschätzt; und eine erste Lenkwinkelprofil-Speichereinheit, die eine Information speichert über eine chronologische Veränderung eines Lenkwinkels eines Fahrzeuges, erfasst durch die Zustandserfassungseinheit (102) für das gesteuerte Objekt, zu der Zeit der vergangenen Spuränderungen, und wenn die Spurveränderungsabsicht der Bedienperson durch die Spurveränderungsabsicht-Abschätzungseinheit abgeschätzt wird, die Steuerungssignal- Erzeugungseinheit (104) für einen idealen Manipulator die Information über die chronologische Veränderung des Lenkwinkels des Fahrzeuges, gespeichert in der ersten Lenkwinkelprofil-Speichereinheit, Bezug nimmt, um ein Lenkprofil des Fahrzeuges zu einer Zeit der letzten Spuränderungen als das ideales- Manipulator- Steuerungssignal zu erzeugen.

20. Steuerungsbetätigung- unterstützende Vorrichtung nach Anspruch 19, **gekennzeichnet durch** eine Einfädelabsicht- Abschätzungseinheit, die eine Einfädelabsicht der Bedienperson abschätzt; und
eine zweite Lenkwinkelprofil- Speichereinheit, die eine Information über die chronologischen Veränderungen eines Lenkwinkels, erfasst **durch** die Zustandserfassungseinheit (102) für das gesteuerte Objekt zu der Zeit des vergangenen Einfädelns speichert, wobei
wenn die Einfädelabsicht der Bedienperson **durch** die Einfädelabsicht- Abschätzungseinheit abgeschätzt wird, die Steuerungssignal- Erzeugungseinheit (104) für den idealen Manipulator auf die Information über die chronologische Veränderung des Lenkwinkels des Fahrzeuges, gespeichert in der zweiten Lenkwinkelprofil-Speichereinheit Bezug nimmt, um ein Lenkwinkelprofil des Fahrzeuges zu der Zeit des vergangenen Einfädelns als das Steuerungssignal für den idealen Manipulator zu erzeugen, und wenn die Umgebungs- Zustandserfassungseinheit (101) eine vorbestimmte Anzahl oder mehr von Fahrzeugen, die auf einer zusammengeführten Spur fahren, erfasst, das Betätigerdrehmoment- Steuerungsunterstützungssystem (109) das

Unterstützungsniveau der Steuerungsbetätigung erhöht.

21. Steuerungsbetätigung- Unterstützungsverfahren zum Unterstützen der Steuerungsbetätigung einer Bedienperson zum Steuern eines steuerungsgesteuerten Objektes (114), aufweisend:

einen Schritt des Erzeugens eines idealen Steuerungspfades des steuerungsgesteuerten Objektes (114) aus Informationen über den Steuerungsbetätigungszustand der Bedienperson und Informationen über die Steuerungsbetätigungsumgebung an der Peripherie des steuerungsgesteuerten Objektes (114);
einen Schritt der Berechnung, als ein ideales Steuerungssignal, eines Steuerungsprofiles eines Betriebssystems für das steuerungsgesteuerte Objekt (114), um entlang des erzeugten idealen Steuerungspfades zu arbeiten;
einen Schritt der Berechnung der Differenz zwischen dem berechneten idealen Steuerungssignal und der Information über den Steuerungsbetätigungszustand;
einen Schritt der Steuerung des Betriebssystems auf der Grundlage der Größe der berechneten Differenz, um die Betätigung der Bedienperson für das Betätigungssystem zu unterstützen; und
einen Schritt des Abschätzens der Genauigkeit, gefordert für die Steuerungsbetätigung des steuerungsgesteuerten Objektes (114), aus der Information über den Steuerungsbetätigungszustand und / oder der Information über die Steuerungsbetätigungsumgebung, wobei bei dem Unterstützungsschritt der Betätigung der Bedienperson das Unterstützungsniveau des Betriebssystems erhöht wird, wenn die abgeschätzte Genauigkeit höher wird.

Revendications

1. Dispositif d'assistance d'opération de commande qui facilite une opération de commande d'un opérateur sur un manipulateur (112) pour la commande d'un objet commandé (114), comprenant :

une unité de détection d'état d'objet commandé (102) qui détecte des informations quant à l'état de l'objet commandé (114) ;
une unité de détection d'état de manipulateur (113) qui détecte des informations quant à l'état du manipulateur (112) ;
une unité de détection d'état d'environnement (101) qui détecte des informations quant à l'état de l'environnement de l'opération de commande à la périphérie de l'objet commandé (114) ;
un système d'assistance d'appareil de commande de couple d'actionneur (109) qui commande un couple additionnel produit par un actionneur (111), **caractérisé par**
une unité de génération d'interaction idéale (103) qui génère la dynamique d'interaction idéale entre l'objet commandé (114) et l'environnement à partir des informations quant à l'objet commandé (114) détecté par l'unité de détection d'état d'objet commandé (102) et l'état environnemental détecté par l'unité de détection d'état d'environnement (101) ;
une unité de génération d'impédance de manipulateur idéale (106) qui génère une impédance idéale pour le manipulateur (112) à partir de la dynamique d'interaction idéale entre l'objet commandé (114) et l'environnement générée par l'unité de génération d'interaction idéale (103) ;
un système d'assistance d'appareil de commande d'impédance de manipulateur (110) qui commande l'impédance du manipulateur (112) d'après l'impédance de manipulateur idéale générée par l'unité de génération d'impédance de manipulateur idéale (106) afin de produire la dynamique d'interaction souhaitée entre l'objet commandé (114) et l'environnement ;
une unité de génération de signal de commande de manipulateur idéal (104) qui génère un signal de commande de manipulateur idéal à partir de la dynamique d'interaction idéale entre l'objet commandé (114) et l'environnement générée par l'unité de génération d'interaction idéale (103) ;
une unité de calcul de différence de signal de commande de manipulateur (107) qui calcule la différence entre le signal de commande de manipulateur idéal généré par l'unité de génération de signal de commande de manipulateur idéal (104) et l'état du manipulateur (112) détecté par l'unité de détection d'état de manipulateur (113) ;
une unité d'estimation de précision d'opération (105) qui estime une précision nécessaire pour l'opération de commande de l'objet commandé (114) à partir de la dynamique d'interaction idéale entre l'objet commandé (114) et l'environnement générée par l'unité de génération d'interaction idéale (103) ;
une unité de génération d'impédance de différence de commande (108) qui génère une impédance de différence de commande à partir de la précision nécessaire estimée par l'unité d'estimation de précision d'opération (105) ; dans lequel
le système d'assistance d'appareil de commande de couple d'actionneur (109) commande le couple additionnel produit par l'actionneur (111)

d'après la grandeur de la différence calculée par l'unité de calcul de différence de signal de commande de manipulateur (107) et l'impédance de différence de commande calculée par l'unité de génération d'impédance de différence de commande (108) afin de faciliter l'opération de commande de l'opérateur sur le manipulateur (112) pour atteindre la précision d'opération nécessaire.

2. Dispositif d'assistance d'opération de commande selon la revendication 1, **caractérisé par** une unité de génération de chemin de commande idéal qui génère un chemin de commande idéal pour l'objet commandé (114) à partir des informations quant à l'état de l'objet commandé (114) détecté par l'unité de détection d'état d'objet commandé (102) et l'état environnemental détecté par l'unité de détection d'état d'environnement (101).

3. Dispositif d'assistance d'opération de commande selon la revendication 2, **caractérisé par** une unité de génération de signal de commande de manipulateur idéal qui génère, en tant que signal de commande de manipulateur idéal, un profil de signal de commande pour commander à l'objet commandé (114) de parcourir le chemin de commande idéal généré par l'unité de génération de chemin de commande idéal.

4. Dispositif d'assistance d'opération de commande selon la revendication 3, **caractérisé par** une unité de prédiction de signal de commande qui prédit des informations quant à l'état d'opération de commande jusqu'à un temps futur prédéterminé, d'après les informations quant à l'état de l'objet commandé (114) détecté par l'unité de détection d'état d'objet commandé (102), dans lequel l'unité de calcul de différence de signal de commande de manipulateur (107) calcule la différence entre le signal de commande de manipulateur idéal, jusqu'à un temps futur prédéterminé, généré par l'unité de génération de signal de commande de manipulateur idéal et les informations quant à l'état d'opération de commande, jusqu'à un temps futur prédéterminé, prédit par l'unité de prédiction de signal de commande.

5. Dispositif d'assistance d'opération de commande selon la revendication 3 ou 4, **caractérisé en ce que** l'unité de calcul de génération de signal de commande de manipulateur idéal (104) utilise un modèle d'opérateur pour calculer le signal de commande de manipulateur idéal à partir des informations quant à l'état de l'objet commandé (114) détecté par l'unité de détection d'état d'objet commandé (102) et des informations quant à l'état de l'environnement d'opération de commande détecté par l'unité de détection d'état d'environnement (101).

6. Dispositif d'assistance d'opération de commande selon l'une quelconque des revendications 1 à 5, **caractérisé en ce que** l'unité de détection d'état d'objet commandé (102) détecte, en tant qu'informations quant à l'état d'objet commandé (114), au moins un élément parmi l'orientation de l'objet commandé (114), sa vitesse, son angle de direction de propagation, son accélération, et sa valeur de manipulateur.

7. Dispositif d'assistance d'opération de commande selon l'une quelconque des revendications 1 à 6, **caractérisé en ce que** l'unité de détection d'état d'environnement (101) détecte, en tant qu'informations quant à l'état de l'environnement d'opération de commande, au moins un élément parmi : les obstacles présents à la périphérie de l'objet commandé (114) ; une barrière courbe-linéaire, une largeur, une rugosité le long du chemin que parcoure l'objet commandé (114) ; et des corps mobiles adjacents à l'objet mené par commande.

8. Dispositif d'assistance d'opération de commande selon l'une quelconque des revendications 1 à 7, **caractérisé en ce que** le système d'assistance d'appareil de commande de couple d'actionneur (109) adapte la règle de force de sortie de l'objet commandé (114) pour commander l'objet commandé (114) et régule le niveau de force ajoutée à l'opération de commande sur le manipulateur (112) de l'opérateur, désignée par règle de force de sortie, afin de réguler le niveau d'assistance de l'opération de commande.

9. Dispositif d'assistance d'opération de commande selon la revendication 8, **caractérisé en ce que** le système d'assistance d'appareil de commande de couple d'actionneur (109) adapte la règle de force de sortie de l'objet commandé (114) pour commander l'objet commandé (114), désignée par règle de force de sortie, afin de réguler le niveau d'assistance de l'opération de commande.

10. Dispositif d'assistance d'opération de commande selon la revendication 8, **caractérisé en ce que** le système d'assistance d'appareil de commande de couple d'actionneur (109) régule le niveau de force ajoutée à l'opération de commande sur le manipulateur (112) de l'opérateur, afin de réguler le niveau d'assistance de l'opération de commande.

11. Dispositif d'assistance d'opération de commande selon l'une quelconque des revendications 1 à 10, **caractérisé par** l'unité d'estimation de charge d'opération de commande qui estime la charge d'opération de commande de l'opérateur, dans lequel le système d'assistance d'appareil de commande de couple d'actionneur (109) augmente le niveau d'assistance de l'opération de commande tandis que

la charge d'opération de commande estimée par l'unité d'estimation de charge d'opération de commande devient plus grande.

12. Dispositif d'assistance d'opération de commande selon l'une quelconque des revendications 8 à 11, **caractérisé en ce que** la règle de force de sortie est une règle de couple de sortie de l'actionneur (111).

13. Dispositif d'assistance d'opération de commande selon la revendication 12, **caractérisé en ce que** le système d'assistance d'appareil de commande de couple d'actionneur (109) change la règle de couple de sortie selon l'impédance de différence de commande générée par l'unité de génération d'impédance de différence de commande (108).

14. Dispositif d'assistance d'opération de commande selon l'une quelconque des revendications 1 à 13, **caractérisé par** :

une unité de calcul de région mobile qui calcule une largeur de la région dans laquelle l'objet commandé (114) peut se déplacer, à partir des informations quant à l'état de l'environnement d'opération de commande détecté par l'unité de détection d'état d'environnement (101) ; et
une unité de calcul de région de commande approximative qui approxime la région mobile calculée par l'unité de calcul de région mobile par une pluralité de régions courbes et de régions droites, dans lequel
lorsque l'unité de détection d'état d'environnement (101) détecte un obstacle à la périphérie de l'objet commandé (114), l'unité de génération d'interaction idéale (103) génère un chemin d'interaction idéale au sein de la région approximée par l'unité de calcul de région de commande approximative.

15. Dispositif d'assistance d'opération de commande selon l'une quelconque des revendications 1 à 14, **caractérisé par** une unité d'estimation de technique d'opération de commande qui estime une technique d'opération de commande de l'opérateur, dans lequel l'unité d'estimation de technique d'opération de commande estime que plus une fréquence de braquages modifiés détectés via un capteur d'angle de braquage disposé dans l'unité de détection d'état d'opération de véhicule (102) est élevée, plus la technique de pilotage de l'opérateur est faible, et le système d'assistance d'appareil de commande de couple d'actionnement (109) augmente le niveau de commande de l'opération de commande tandis que la technique d'opération de commande de l'opérateur estimée par l'unité d'estimation de technique d'opération de commande devient plus petite.

16. Dispositif d'assistance d'opération de commande selon la revendication 14 ou 15, **caractérisé par** une unité de détermination de condition de commande qui détermine la condition de commande à un moment où l'opération de commande et/ou une unité de détermination de fuseau horaire détermine le fuseau horaire au moment de l'opération de commande, dans lequel lorsque la condition de commande déterminée par l'unité de détermination de condition de commande est mauvaise et/ou lorsque le fuseau horaire déterminé par l'unité de détermination de fuseau horaire est la nuit, l'unité de génération d'interaction idéale (103) adapte le chemin de commande idéal généré et le système d'assistance d'appareil de commande de couple d'actionneur (109) augmente le niveau d'assistance de l'opération de commande.

17. Dispositif d'assistance d'opération de commande selon l'une quelconque des revendications 14 à 16, **caractérisé par** une unité de détection d'opération détériorée qui détecte une opération détériorée de l'opérateur, dans lequel lorsque l'opération détériorée de l'opérateur est détectée par l'unité de détection d'opération détériorée, l'unité de génération d'interaction idéale (103) corrige le chemin de commande idéal généré, et le système d'assistance d'appareil de commande de couple d'actionneur (109) augmente le niveau d'assistance de l'opération de commande.

18. Dispositif d'assistance d'opération de commande selon l'une quelconque des revendications 1 à 17, **caractérisé en ce que** le système d'assistance d'appareil de commande de couple d'actionneur (109) augmente le niveau d'assistance de l'opération de commande alors que le nombre de corps mobiles, adjacents à l'objet commandé (114), détectés par l'unité de détection d'état d'environnement (101), devient plus grand.

19. Dispositif d'assistance d'opération de commande selon l'une quelconque des revendications 1 à 18, **caractérisé en ce que** l'objet commandé (114) est un véhicule, le dispositif comprend une unité d'estimation d'intention de changement de voie qui estime une intention de changement de voie de l'opérateur ; et une première unité de stockage de profil d'angle de braquage qui stocke des informations quant à un changement chronologique d'un angle de braquage d'un véhicule détecté par l'unité de détection d'état d'objet commandé (102) au moment de changements de voie antérieurs, et lorsque l'intention de changement de voie de l'opérateur est estimé par l'unité d'estimation d'intention de changement de voie, l'unité de génération de signal de commande de manipulateur idéal (104) référence l'information quant au changement chronologique de l'angle de

braquage du véhicule, stockée dans la première unité de stockage de profil d'angle de braquage, afin de générer un profil de braquage du véhicule au moment du changement de voie antérieur, en tant que signal de commande de manipulateur idéal.

20. Dispositif d'assistance d'opération de commande selon la revendication 19, **caractérisé par** :

une unité d'estimation d'intention de convergence qui estime l'intention de convergence de l'opérateur ; et
une seconde unité de stockage de profil d'angle de braquage qui stocke des informations quant aux changements chronologiques d'un angle de braquage détectés par l'unité de détection d'état d'objet commandé (102) au moment de convergence antérieure, dans lequel
lorsque l'intention de convergence de l'opérateur est estimée par l'unité d'estimation d'intention de convergence, l'unité de génération de signal de commande de manipulateur idéal (104) référence les informations quant au changement chronologique de l'angle de braquage du véhicule, stockée dans la seconde unité de stockage de profil d'angle de braquage, afin de générer un profil de braquage du véhicule au moment d'une convergence antérieure, en tant que signal de commande de manipulateur idéal, et lorsque l'unité de détection d'état d'environnement (101) détecte un nombre prédéterminé ou supérieur de véhicules parcourant une voie convergente, le système d'assistance d'appareil de commande de couple d'actionneur (109) augmente le niveau d'assistance de l'opération de commande.

21. Procédé d'assistance d'opération de commande pour faciliter l'opération de commande d'un opérateur pour la commande d'un objet commandé par commande (114), comprenant :

une étape de génération d'un chemin de commande idéal de l'objet commandé par commande (114) à partir d'informations quant à l'état d'opération de commande de l'opérateur et d'informations quant à l'environnement d'opération de commande à la périphérie de l'objet commandé par commande (114) ;
une étape de calcul, en tant que signal de commande idéal, d'un profil de commande d'un système d'opération pour que l'objet commandé par commande (114) fonctionne le long du chemin de commande idéal généré ;
une étape de calcul de la différence entre le signal de commande idéal calculé et les informations quant à l'état d'opération de commande ;
une étape de commande du système d'opération d'après la grandeur de la différence calculée afin de faciliter l'opération de l'opérateur pour le système d'opération ; et
une étape d'estimation de la précision nécessaire pour l'opération de commande de l'objet commandé par commande (114), à partir des informations quant à l'état d'opération de commande et/ou des informations quant à l'environnement d'opération de commande, dans laquelle lors de l'étape d'assistance de l'opération de l'opérateur, le niveau d'assistance du système d'opération est augmenté alors que la précision estimée devient plus élevée.

FIG. 1

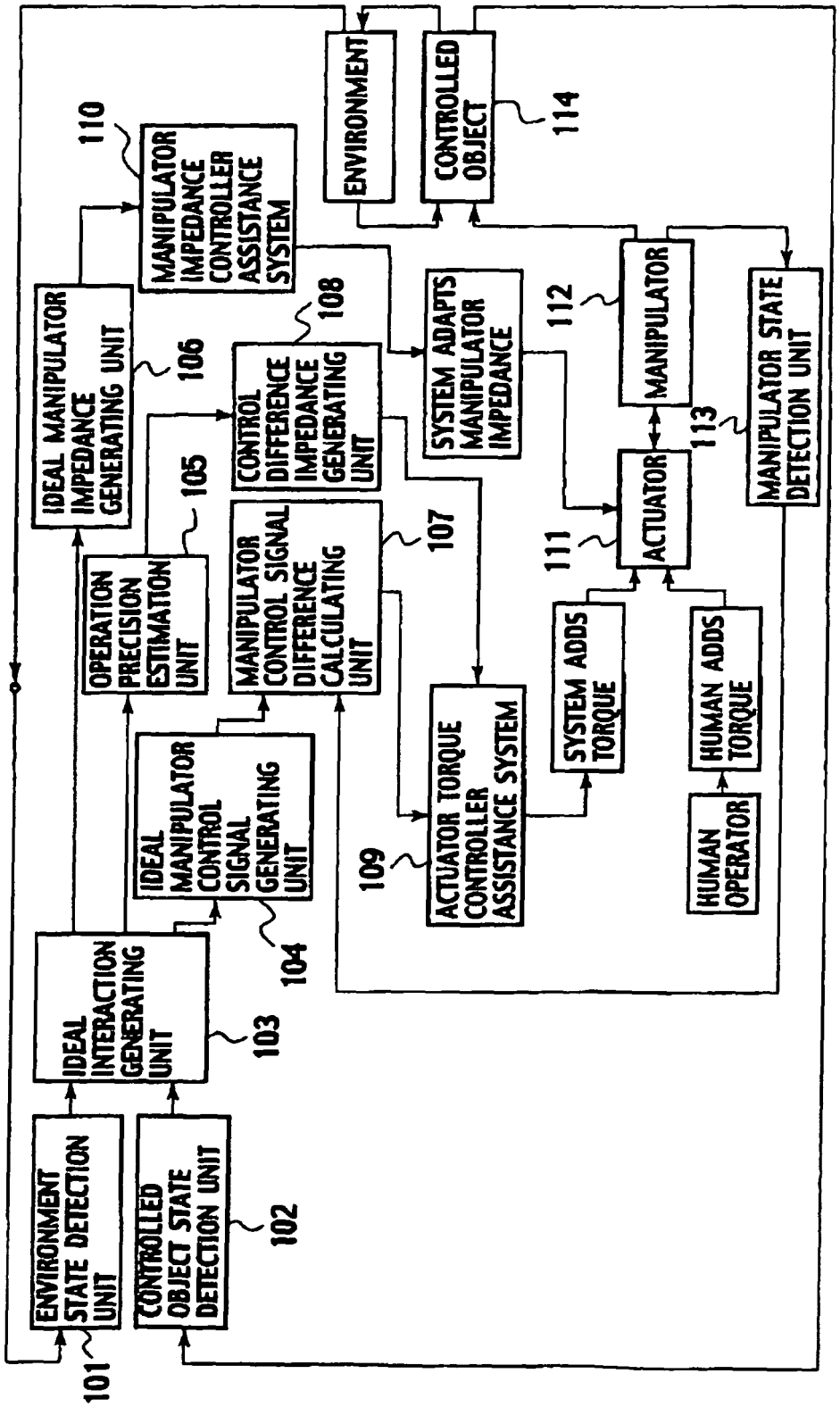

ENVIRONMENT STATE DETECTION UNIT
101
CONTROLLED OBJECT STATE DETECTION UNIT
102
IDEAL INTERACTION GENERATING UNIT
103
IDEAL MANIPULATOR CONTROL SIGNAL GENERATING UNIT
104
OPERATION PRECISION ESTIMATION UNIT
105
IDEAL MANIPULATOR IMPEDANCE GENERATING UNIT
106
MANIPULATOR CONTROL SIGNAL DIFFERENCE CALCULATING UNIT
107
CONTROL DIFFERENCE IMPEDANCE GENERATING UNIT
108
ACTUATOR TORQUE CONTROLLER ASSISTANCE SYSTEM
109
MANIPULATOR IMPEDANCE CONTROLLER ASSISTANCE SYSTEM
110
ACTUATOR
111
SYSTEM ADAPTS MANIPULATOR IMPEDANCE
112
MANIPULATOR
113
CONTROLLED OBJECT
114
ENVIRONMENT
SYSTEM ADDS TORQUE
HUMAN ADDS TORQUE
HUMAN OPERATOR
MANIPULATOR STATE DETECTION UNIT

FIG. 2

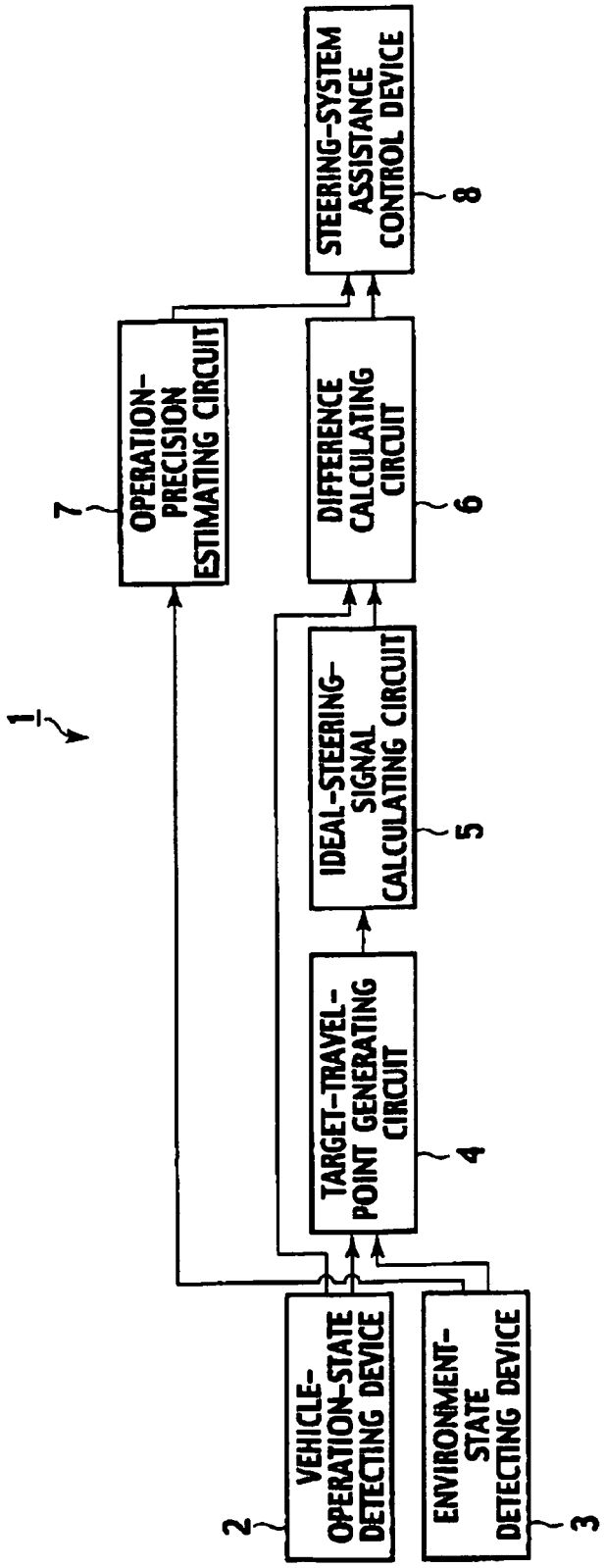

1
2
VEHICLE-OPERATION-STATE DETECTING DEVICE
3
ENVIRONMENT-STATE DETECTING DEVICE
4
TARGET-TRAVEL-POINT GENERATING CIRCUIT
5
IDEAL-STEERING-SIGNAL CALCULATING CIRCUIT
6
DIFFERENCE CALCULATING CIRCUIT
7
OPERATION-PRECISION ESTIMATING CIRCUIT
8
STEERING-SYSTEM ASSISTANCE CONTROL DEVICE

FIG. 3

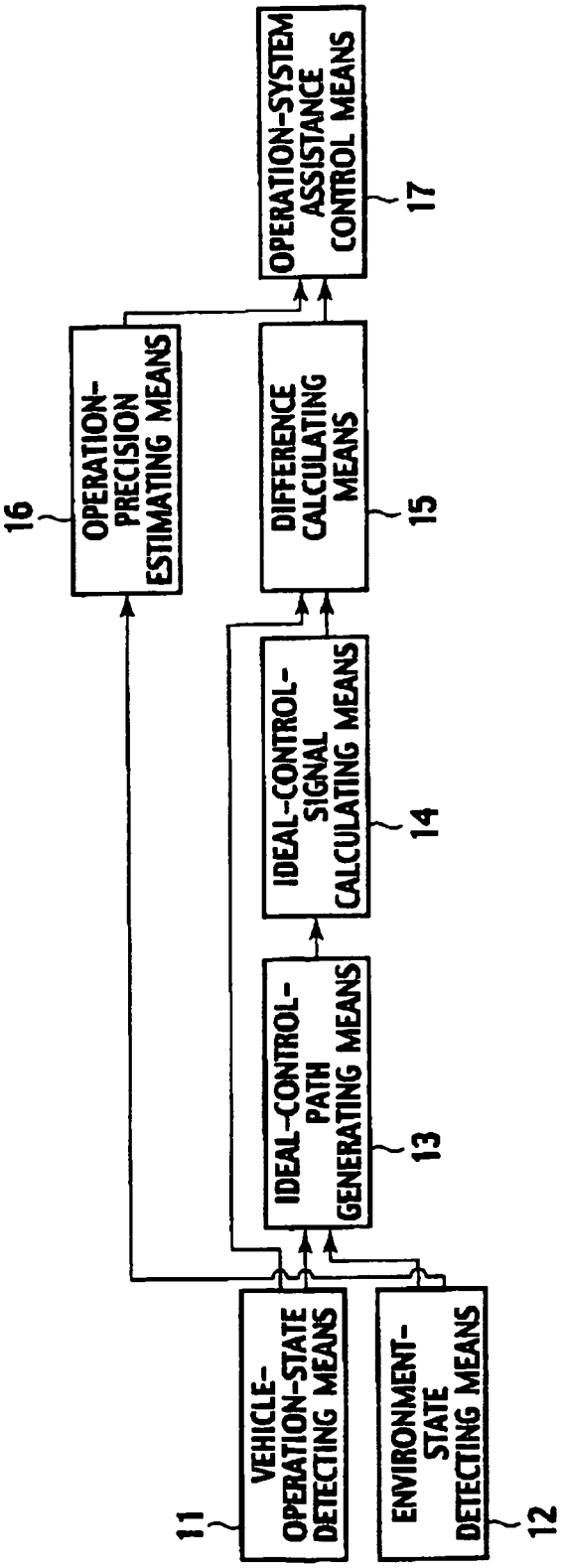

VEHICLE-OPERATION-STATE DETECTING MEANS
11
ENVIRONMENT-STATE DETECTING MEANS
12
IDEAL-CONTROL-PATH GENERATING MEANS
13
IDEAL-CONTROL-SIGNAL CALCULATING MEANS
14
DIFFERENCE CALCULATING MEANS
15
OPERATION-PRECISION ESTIMATING MEANS
16
OPERATION-SYSTEM ASSISTANCE CONTROL MEANS
17

FIG. 4

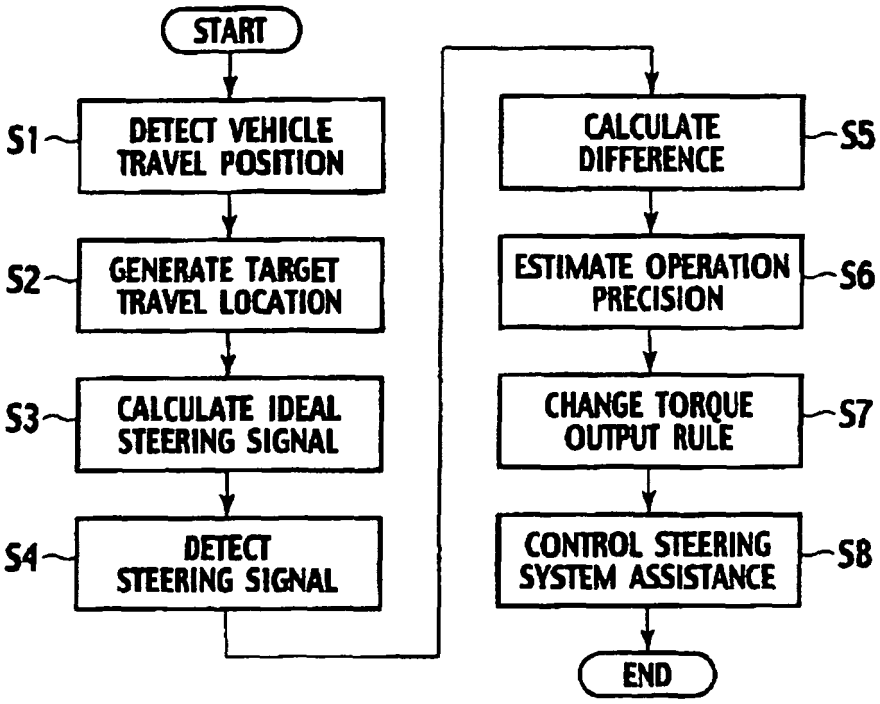

START
S1
DETECT VEHICLE TRAVEL POSITION
S2
GENERATE TARGET TRAVEL LOCATION
S3
CALCULATE IDEAL STEERING SIGNAL
S4
DETECT STEERING SIGNAL
S5
CALCULATE DIFFERENCE
S6
ESTIMATE OPERATION PRECISION
S7
CHANGE TORQUE OUTPUT RULE
S8
CONTROL STEERING SYSTEM ASSISTANCE
END

FIG. 5

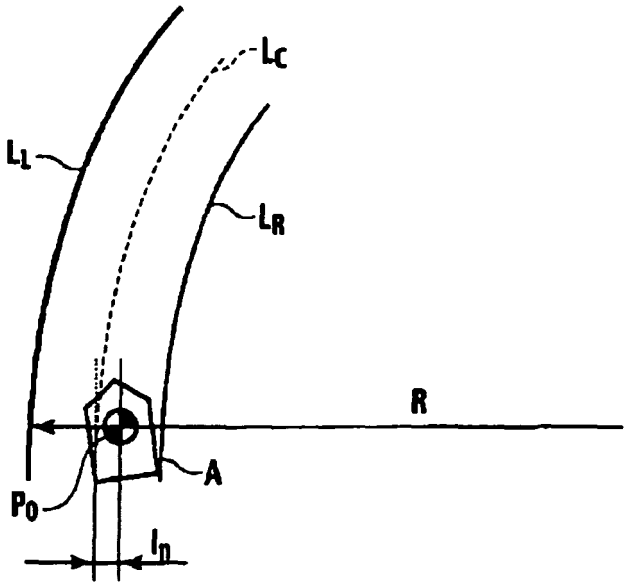

L_C
L_L
L_R
R
A
P_0
l_n

FIG. 6

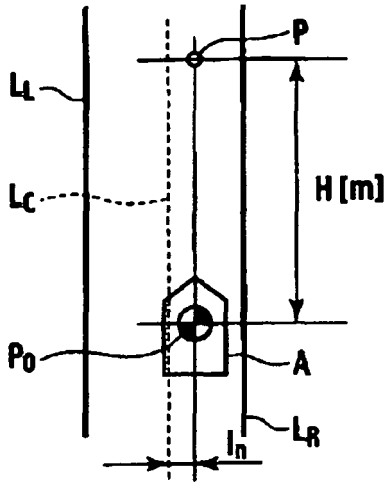


FIG. 7

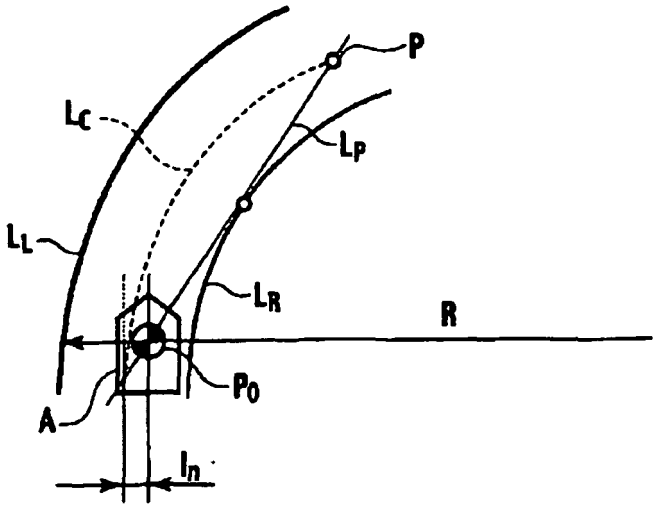


FIG. 8

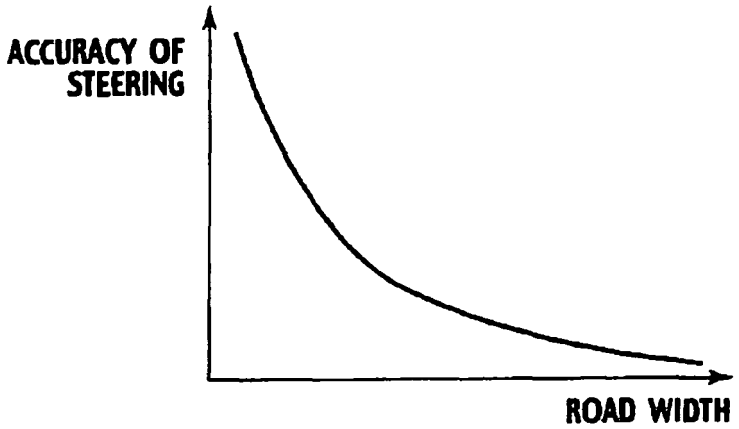

ACCURACY OF STEERING
ROAD WIDTH

FIG. 9

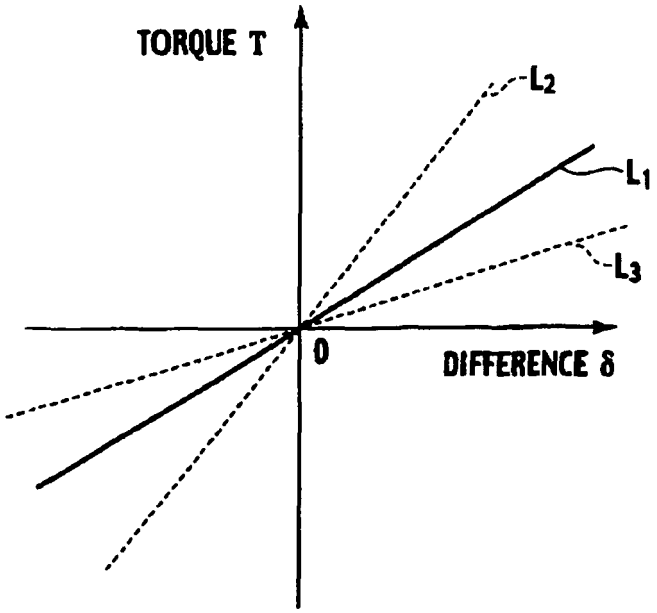

TORQUE T
L2
L1
L3
0
DIFFERENCE δ

FIG. 10

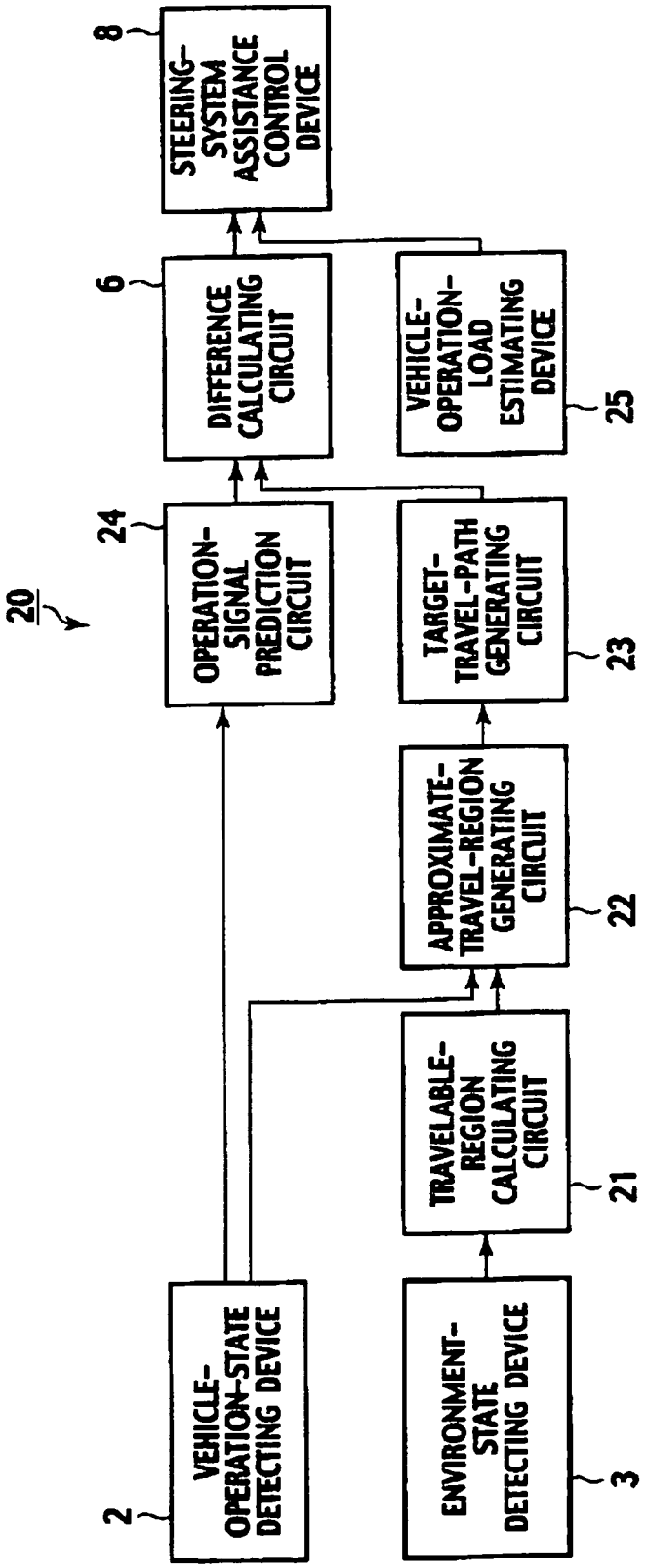

8
STEERING-SYSTEM ASSISTANCE CONTROL DEVICE
6
DIFFERENCE CALCULATING CIRCUIT
VEHICLE-OPERATION-LOAD ESTIMATING DEVICE
25
20
24
OPERATION-SIGNAL PREDICTION CIRCUIT
TARGET-TRAVEL-PATH GENERATING CIRCUIT
23
APPROXIMATE-TRAVEL-REGION GENERATING CIRCUIT
22
TRAVELABLE-REGION CALCULATING CIRCUIT
21
2
VEHICLE-OPERATION-STATE DETECTING DEVICE
ENVIRONMENT-STATE DETECTING DEVICE
3

FIG. 11

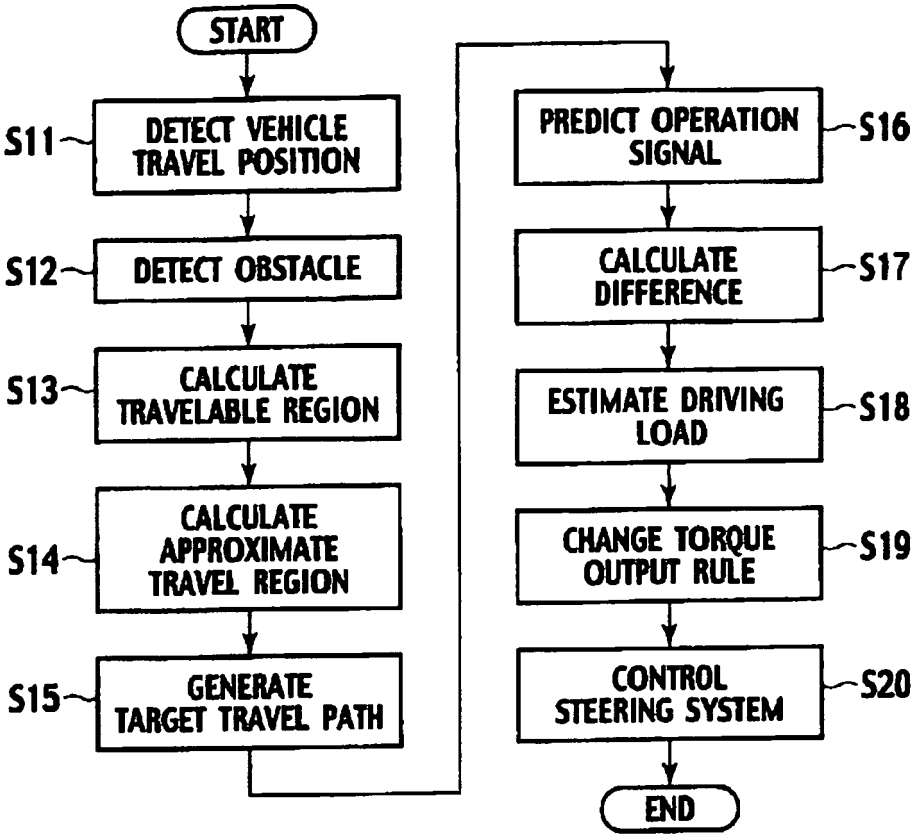

START
S11
DETECT VEHICLE TRAVEL POSITION
S12
DETECT OBSTACLE
S13
CALCULATE TRAVELABLE REGION
S14
CALCULATE APPROXIMATE TRAVEL REGION
S15
GENERATE TARGET TRAVEL PATH
S16
PREDICT OPERATION SIGNAL
S17
CALCULATE DIFFERENCE
S18
ESTIMATE DRIVING LOAD
S19
CHANGE TORQUE OUTPUT RULE
S20
CONTROL STEERING SYSTEM
END

FIG. 12

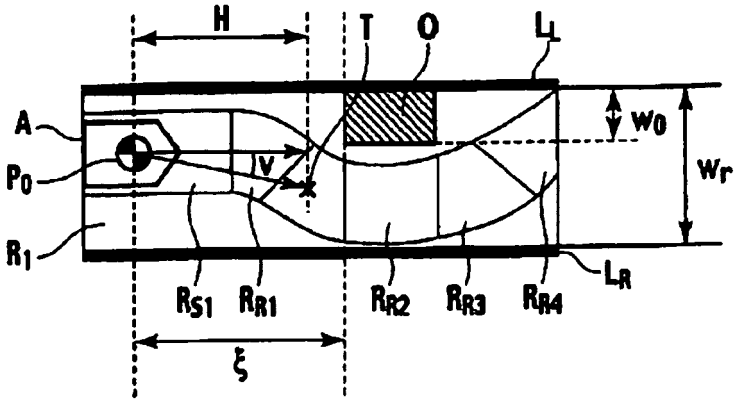

H
T
O
L
A
P0
R1
V
W0
Wr
RS1
RR1
RR2
RR3
RR4
LR
ξ

FIG. 13

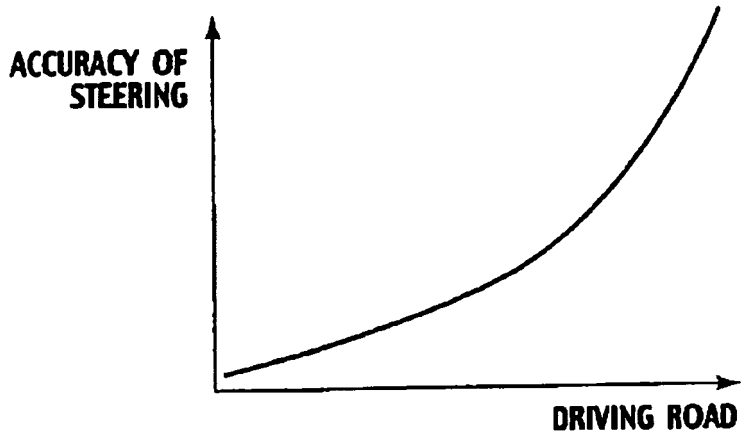

ACCURACY OF STEERING
DRIVING ROAD

FIG. 14

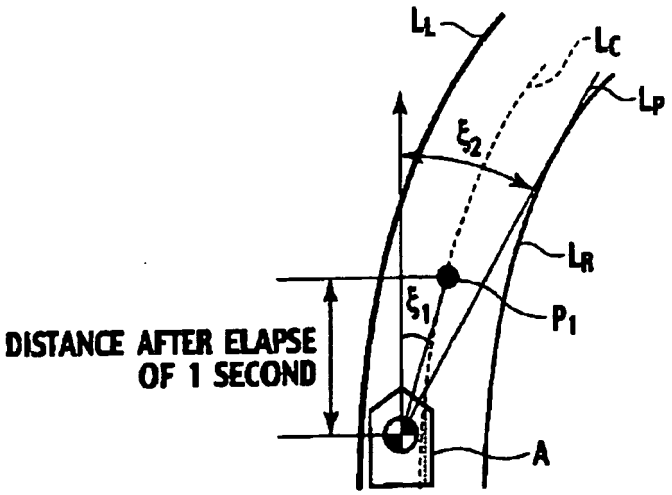

L_L
L_C
L_P
ξ_2
L_R
ξ_1
P_1
DISTANCE AFTER ELAPSE OF 1 SECOND
A

FIG. 15

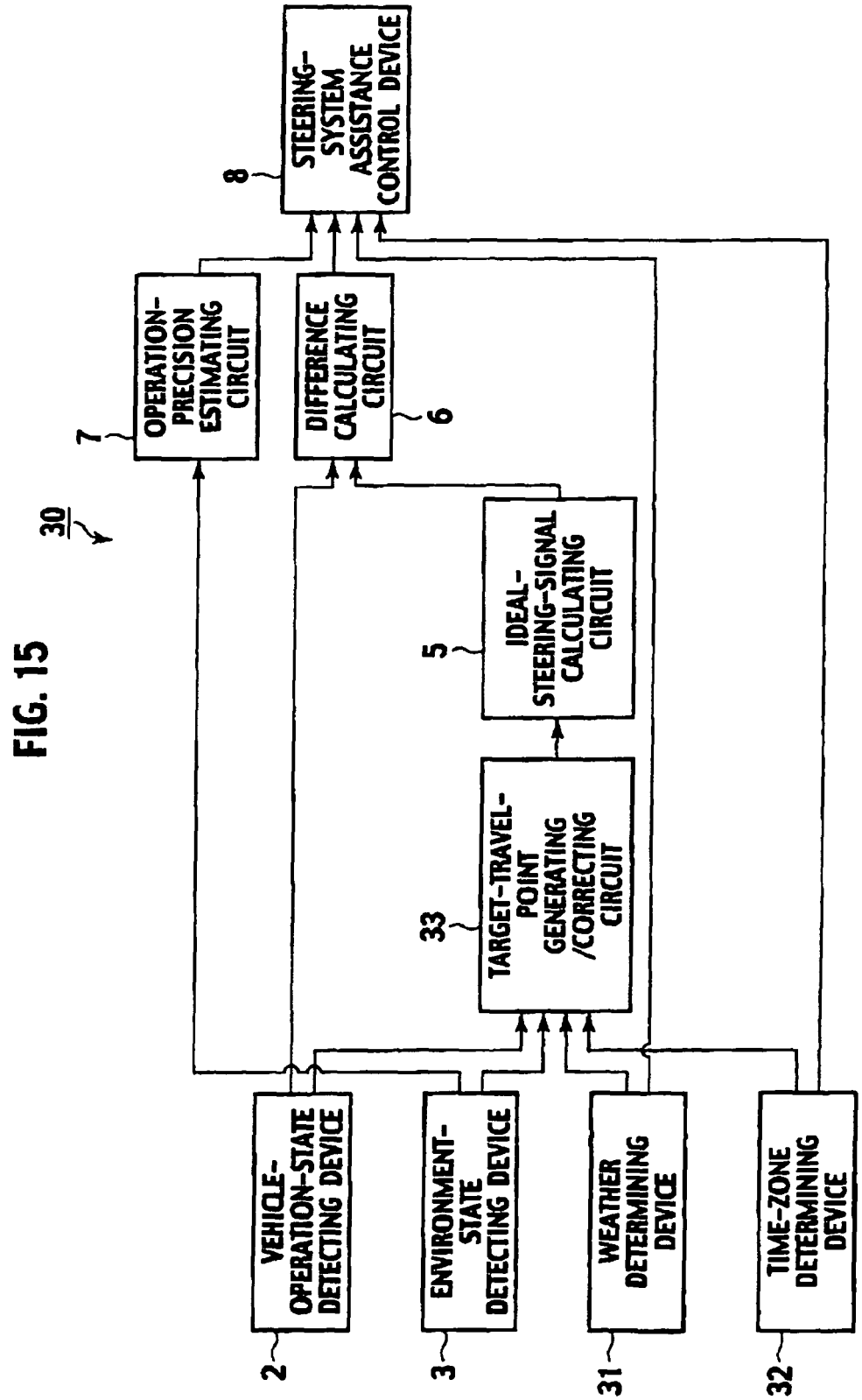

30
STEERING-SYSTEM ASSISTANCE CONTROL DEVICE
8
OPERATION-PRECISION ESTIMATING CIRCUIT
7
DIFFERENCE CALCULATING CIRCUIT
6
IDEAL-STEERING-SIGNAL CALCULATING CIRCUIT
5
TARGET-TRAVEL-POINT GENERATING /CORRECTING CIRCUIT
33
VEHICLE-OPERATION-STATE DETECTING DEVICE
2
ENVIRONMENT-STATE DETECTING DEVICE
3
WEATHER DETERMINING DEVICE
31
TIME-ZONE DETERMINING DEVICE
32

FIG. 16

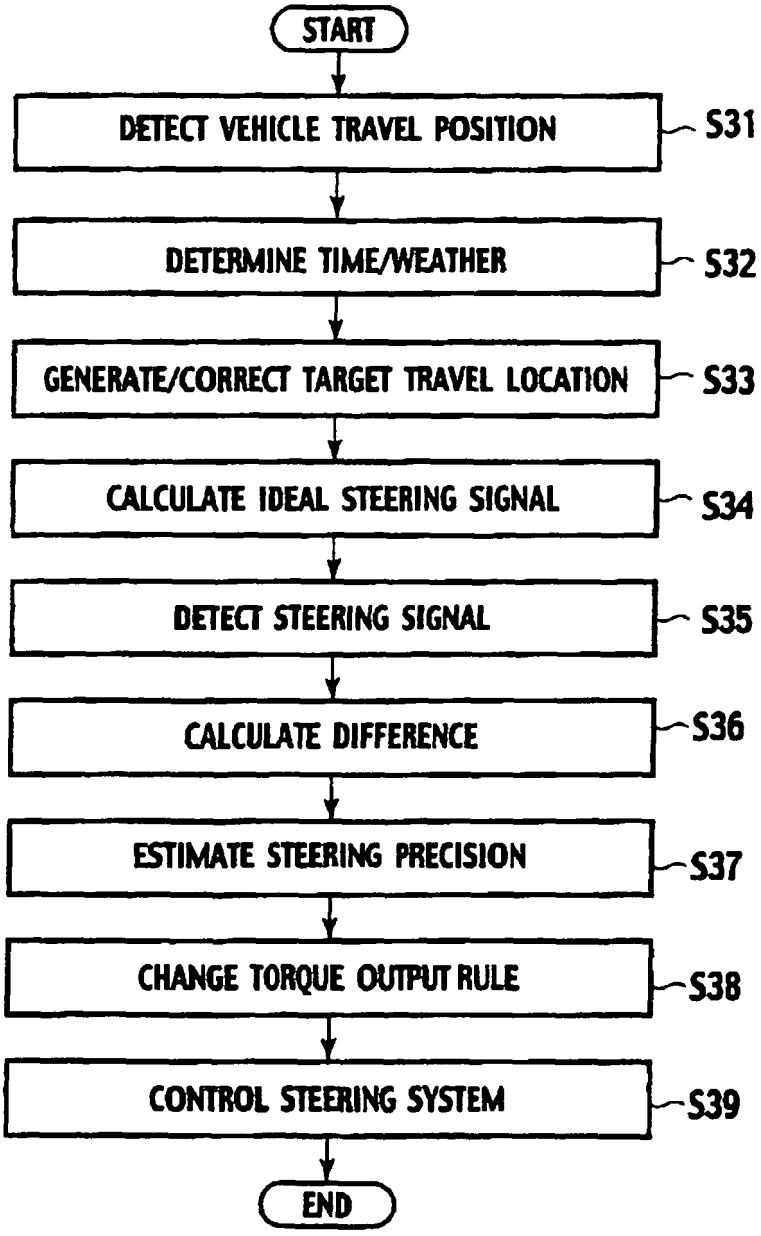

START
DETECT VEHICLE TRAVEL POSITION
S31
DETERMINE TIME/WEATHER
S32
GENERATE/CORRECT TARGET TRAVEL LOCATION
S33
CALCULATE IDEAL STEERING SIGNAL
S34
DETECT STEERING SIGNAL
S35
CALCULATE DIFFERENCE
S36
ESTIMATE STEERING PRECISION
S37
CHANGE TORQUE OUTPUT RULE
S38
CONTROL STEERING SYSTEM
S39
END

FIG. 17

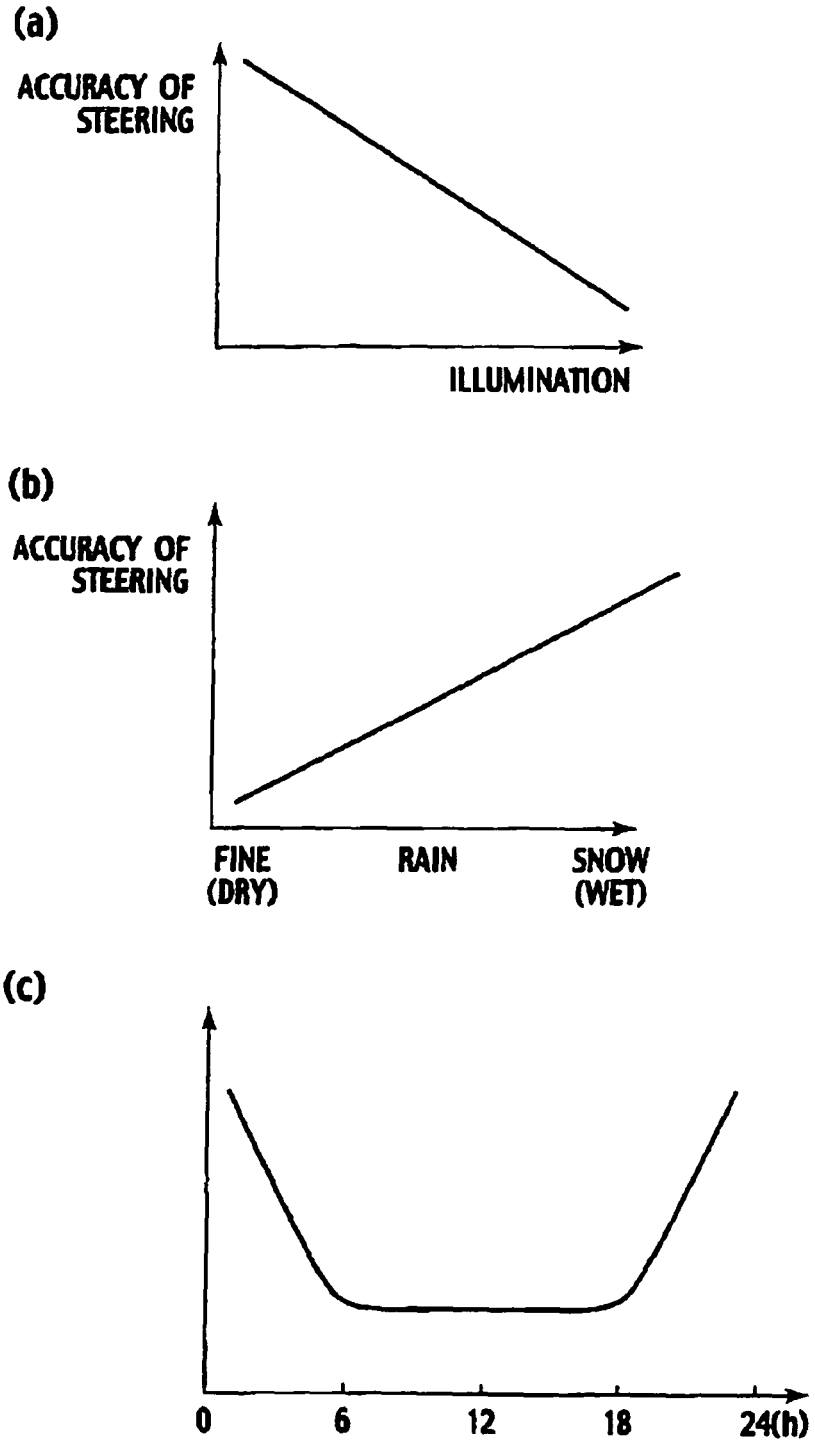

(a)
ACCURACY OF STEERING
ILLUMINATION
(b)
ACCURACY OF STEERING
FINE (DRY)
RAIN
SNOW (WET)
(c)
0
6
12
18
24(h)

FIG. 18

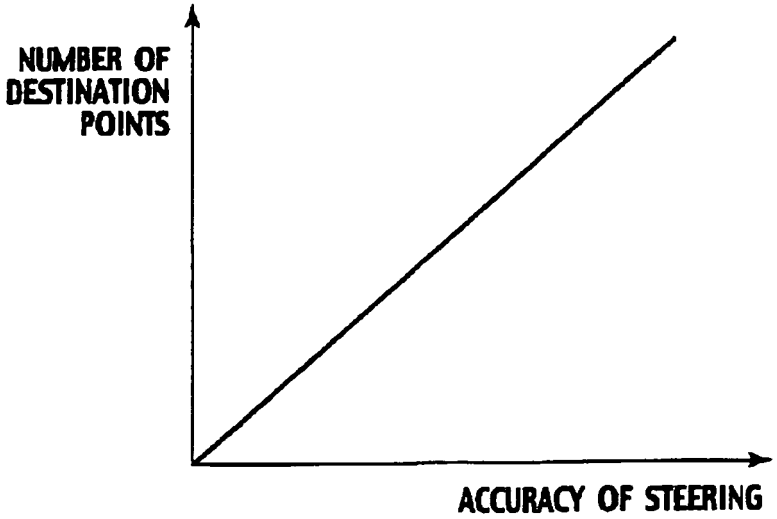


FIG. 19

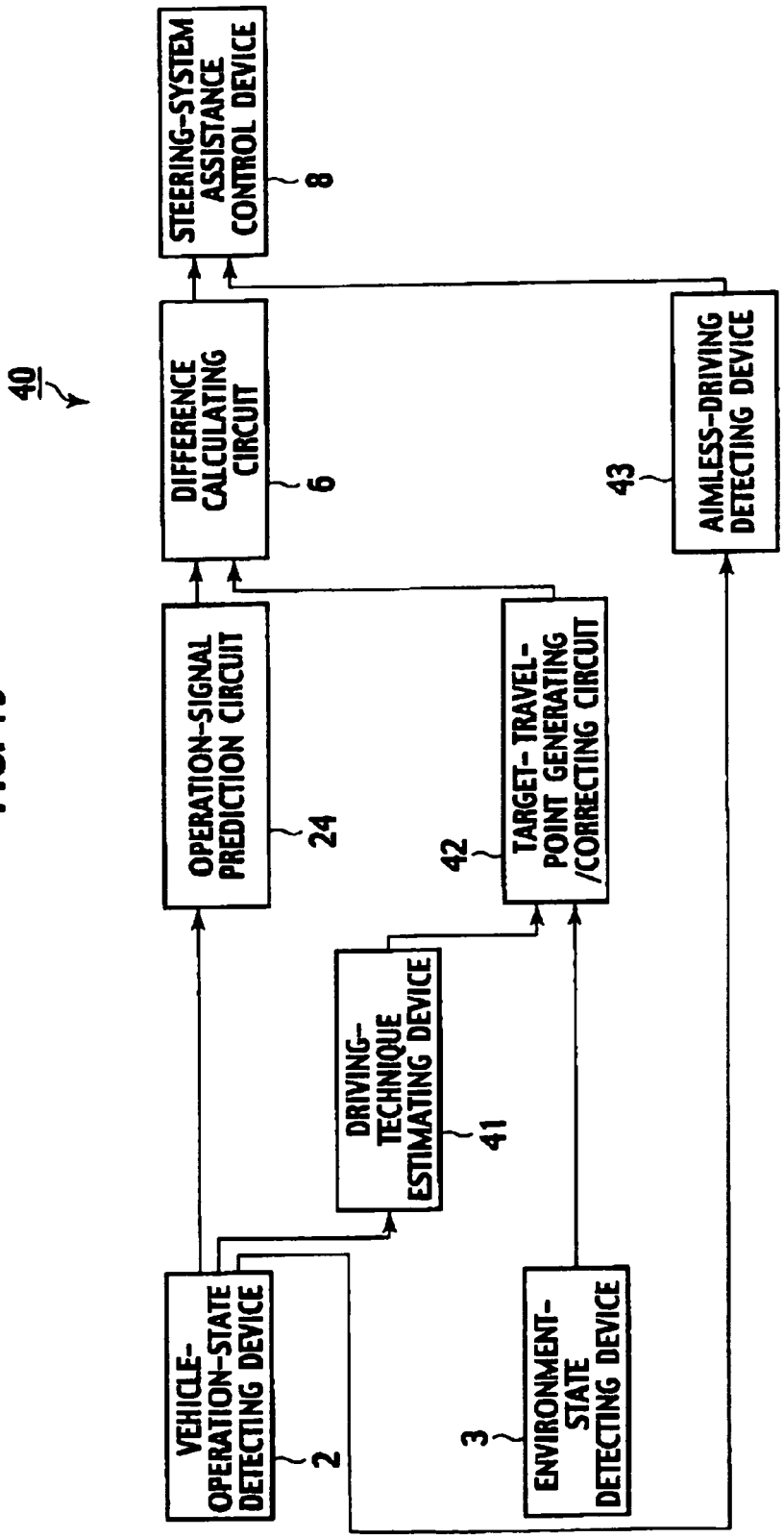

40
STEERING-SYSTEM ASSISTANCE CONTROL DEVICE
8
DIFFERENCE CALCULATING CIRCUIT
6
43
AIMLESS-DRIVING DETECTING DEVICE
OPERATION-SIGNAL PREDICTION CIRCUIT
24
42
TARGET-TRAVEL-POINT GENERATING /CORRECTING CIRCUIT
DRIVING-TECHNIQUE ESTIMATING DEVICE
41
VEHICLE-OPERATION-STATE DETECTING DEVICE
2
3
ENVIRONMENT-STATE DETECTING DEVICE

FIG. 20

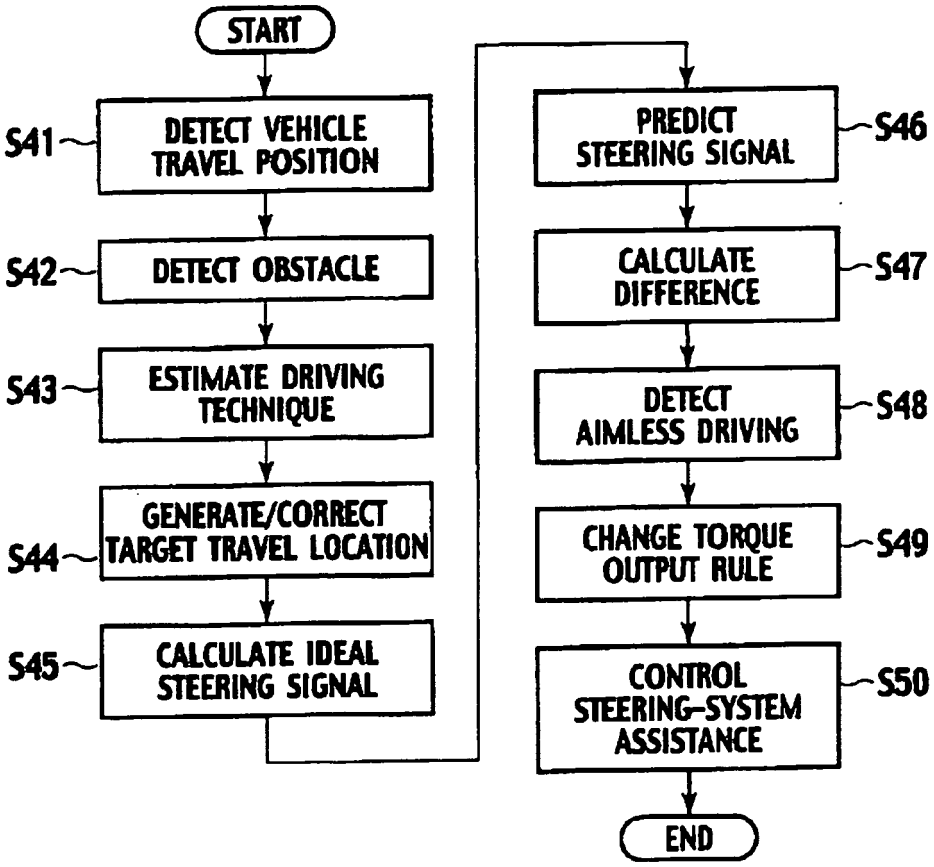

START
S41
DETECT VEHICLE TRAVEL POSITION
S42
DETECT OBSTACLE
S43
ESTIMATE DRIVING TECHNIQUE
S44
GENERATE/CORRECT TARGET TRAVEL LOCATION
S45
CALCULATE IDEAL STEERING SIGNAL
S46
PREDICT STEERING SIGNAL
S47
CALCULATE DIFFERENCE
S48
DETECT AIMLESS DRIVING
S49
CHANGE TORQUE OUTPUT RULE
S50
CONTROL STEERING-SYSTEM ASSISTANCE
END

FIG. 21

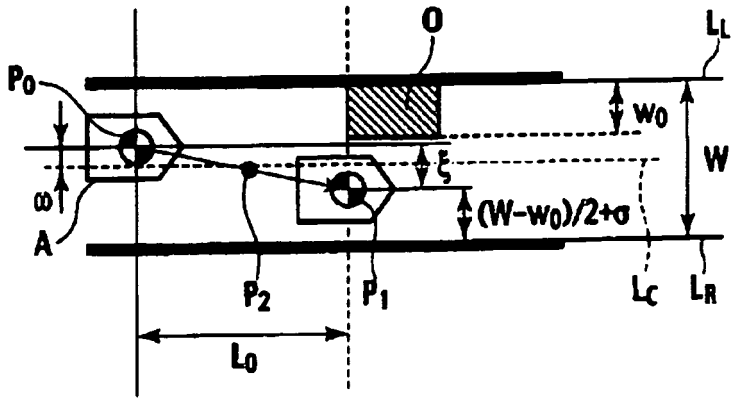

O
L_L
P_0
w_0
W
ξ
ω
A
$(W-w_0)/2+\sigma$
P_2
P_1
L_C
L_R
L_0

FIG. 22

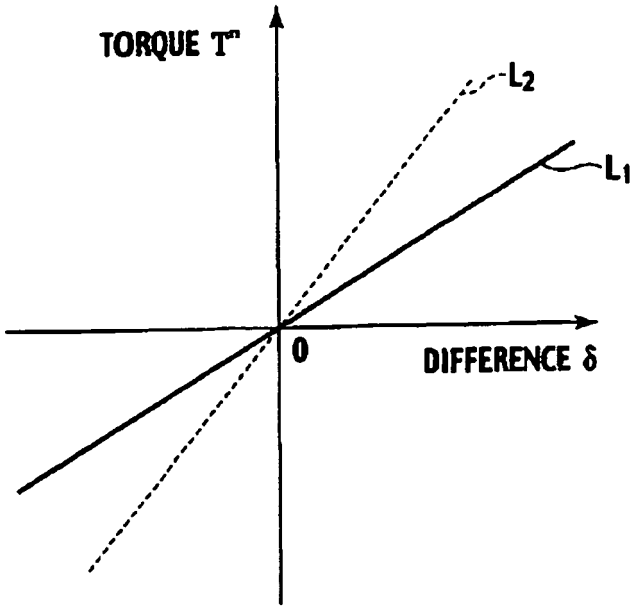


FIG. 23

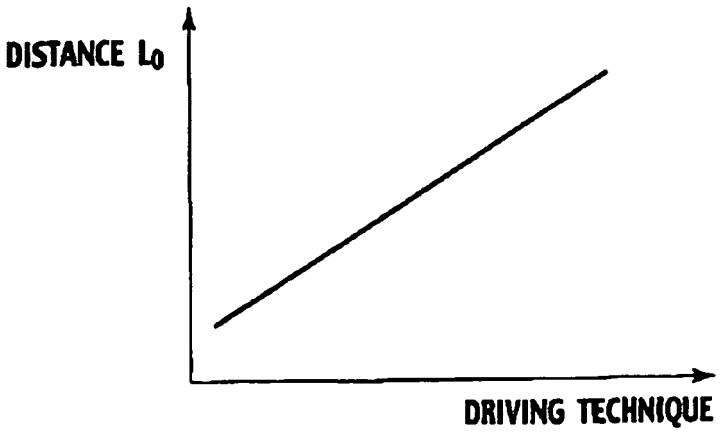


FIG. 24

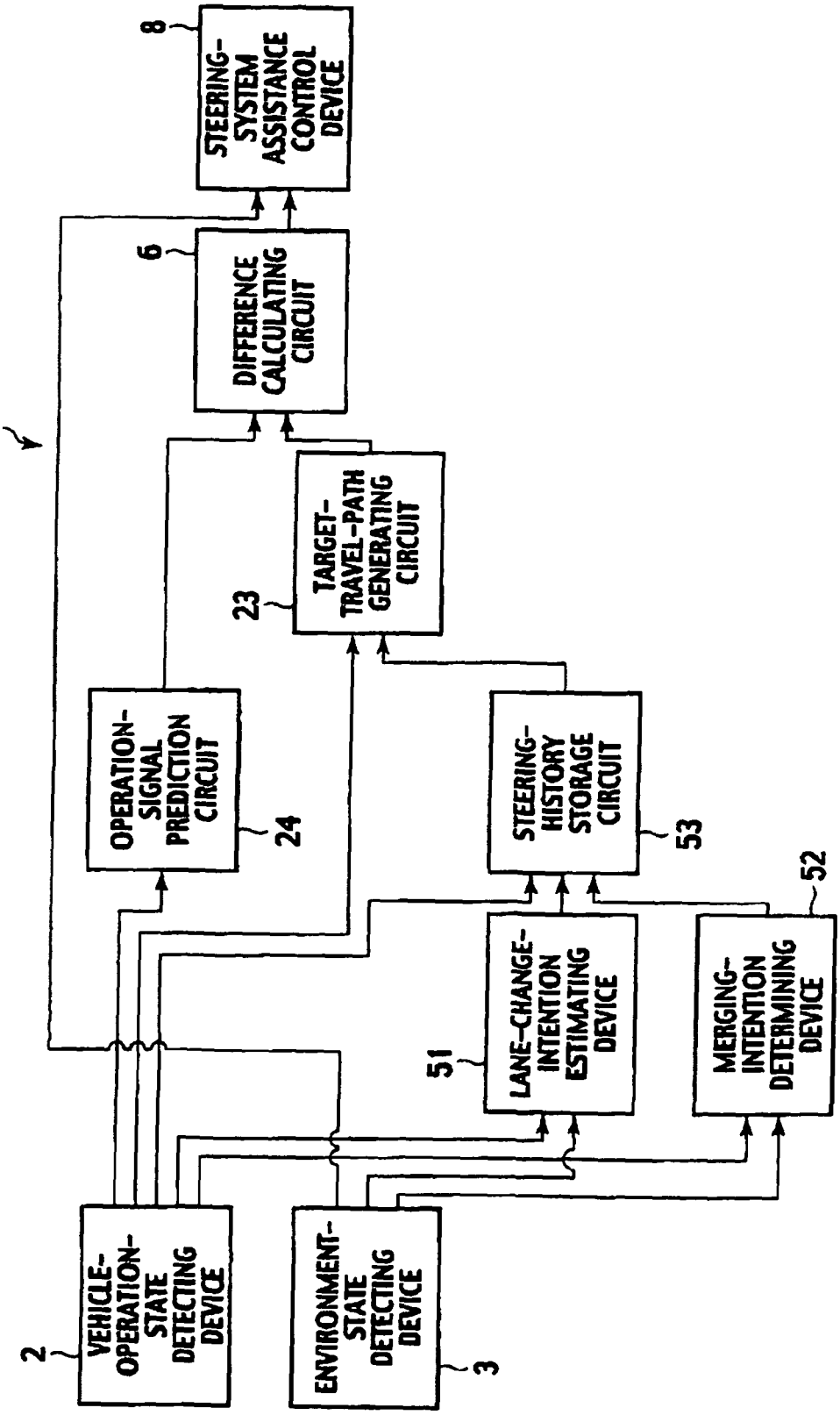

50
8
STEERING-SYSTEM ASSISTANCE CONTROL DEVICE
6
DIFFERENCE CALCULATING CIRCUIT
23
TARGET-TRAVEL-PATH GENERATING CIRCUIT
OPERATION-SIGNAL PREDICTION CIRCUIT
24
STEERING-HISTORY STORAGE CIRCUIT
53
52
51
LANE-CHANGE-INTENTION ESTIMATING DEVICE
MERGING-INTENTION DETERMINING DEVICE
2
VEHICLE-OPERATION-STATE DETECTING DEVICE
ENVIRONMENT-STATE DETECTING DEVICE
3

FIG. 25

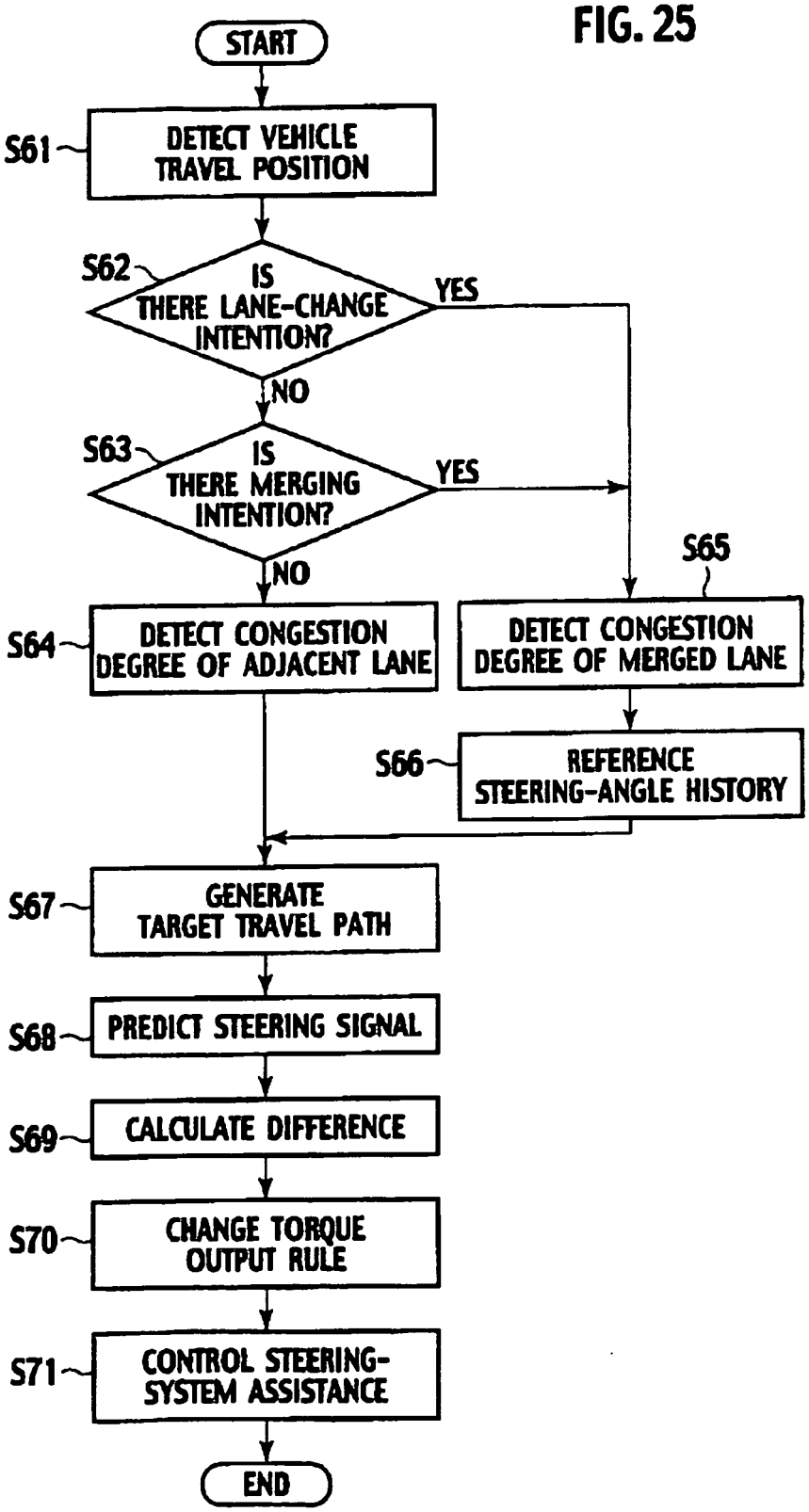
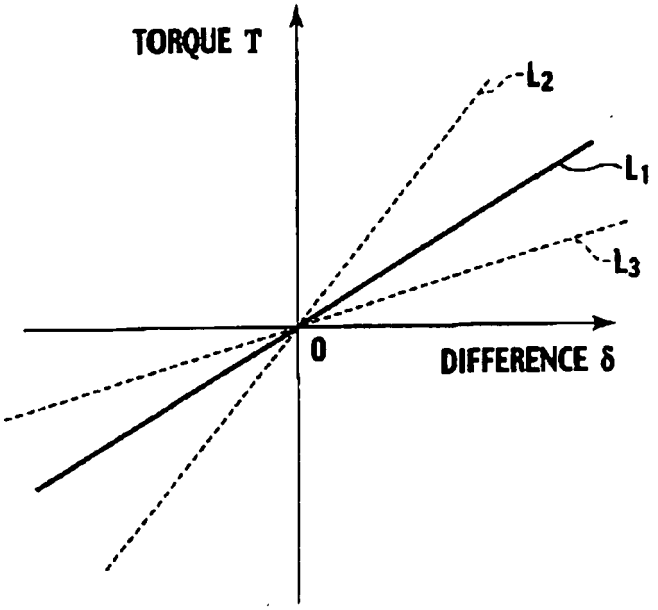

START
S61
DETECT VEHICLE TRAVEL POSITION
S62
IS THERE LANE-CHANGE INTENTION?
YES
NO
S63
IS THERE MERGING INTENTION?
YES
NO
S64
DETECT CONGESTION DEGREE OF ADJACENT LANE
S65
DETECT CONGESTION DEGREE OF MERGED LANE
S66
REFERENCE STEERING-ANGLE HISTORY
S67
GENERATE TARGET TRAVEL PATH
S68
PREDICT STEERING SIGNAL
S69
CALCULATE DIFFERENCE
S70
CHANGE TORQUE OUTPUT RULE
S71
CONTROL STEERING-SYSTEM ASSISTANCE
END

FIG. 26



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- DE 102006033458 A1 **[0001]**
- EP 1889775 A2 **[0002]**
- JP 2007305079 A **[0003]**
- JP 2007182198 A **[0004]**
- JP H9156528 B **[0005]**